HYDRAULIC POWER

AND

HYDRAULIC MACHINERY.

BY

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TO

THE RIGHT HONOURABLE LORD ARMSTRONG,

C.B., LL.D., D.C.L., F.R.S.,

The Originator of the Modern Hydraulic System,

THIS WORK IS CORDIALLY INSCRIBED

IN GRATEFUL ACKNOWLEDGMENT

Of much kindness shown in bygone days

TO HIS FORMER ASSISTANT,

THE AUTHOR.

PREFACE TO THE SECOND EDITION.

SINCE the First Edition of this work was published I have had constantly in view the desirability of enlarging and improving it. The Second Edition is the outcome of this, and will be found to contain much new matter, and a better treatment of old, by which its usefulness will be enhanced. The limits within which it has to be confined necessarily involve compression, both of subjects and of descriptions, but I think the illustrations selected of the innumerable applications of Hydraulic Power will be considered to fairly meet the circumstances. I desire to acknowledge most cordially my indebtedness to the many professional friends who have afforded me information, and otherwise assisted in the preparation of the book.

HENRY ROBINSON.

13 VICTORIA STREET,
WESTMINSTER, *June*, 1893.

PREFACE TO THE FIRST EDITION.

THE increasing interest taken in Water-pressure Machinery, and the extended field which has opened out of late years for its employment, have led me to record, in a form convenient for reference, existing experience in this branch of Engineering. In this task I have availed myself of the information published in the *Proceedings* of the Institution of Civil Engineers, the Institution of Mechanical Engineers, the Iron and Steel Institute, and of other Societies. I have thus not confined myself within the range of my own professional practice, but have utilised the experience of others wherever I have found that it would increase the usefulness of the book.

It affords me much pleasure to acknowledge the ready response that has invariably followed any request for particulars or for drawings to enable me to illustrate the varieties of Hydraulic Apparatus to which I desired to refer, and I believe that I have recognised in the proper places throughout the work my obligations to all who have thus kindly assisted me.

At the commencement, I refer briefly to the "Flow of water under pressure," and show the practical value of some interesting experiments which have recently been made, and which have enabled new formulæ to be deduced for the discharge from pipes. The employment of water-pressure mains, to transmit power through the streets of a town on

the principle which I have termed "Power co-operation," is steadily gaining ground. The first works of the kind were those which I carried out in Hull in 1876, and the promotion of similar undertakings in other towns will afford an increased field for utilising hydraulic power.

Whilst describing the most interesting types of Hydraulic Machinery, I have abstained alike from criticisms on the details of construction, and from any attempts to lay down fixed rules for the employment of any particular appliance. The conditions which render one form of appliance more suitable than another vary in almost every case, so that each requires to be dealt with according to the practical circumstances which govern it.

As my earliest experiences in this branch of my practice were gained nearly thirty years ago, when with Sir William (now Lord) Armstrong, I have dedicated this book to him; and his friendly acceptance of this dedication has enabled me, in these later days, to refer to an association which I look back upon with pleasure and pride.

HENRY ROBINSON.

November, 1886.

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THE weight of a cubic foot of distilled water is 62·499 lbs. avoirdupois at a temperature of 39° Fahrenheit. At a temperature of 62° the weight of a cubic foot of water is 62·355 lbs. Although water has been proved by experiment to be compressible (but very slightly) under great pressures, for all practical purposes it is taken as incompressible. The compressibility of water is one twenty-thousandth for an increase in pressure equivalent to an atmosphere.

DISCHARGE THROUGH ORIFICES.

Torricelli discovered in 1643 that the velocity of a fluid flowing through an orifice in a vessel is approximately equal to that which a solid body would acquire in falling a height corresponding to the distance between the level of the fluid in that vessel and the centre of the orifice. Employing symbols to represent this:—If v is taken for the velocity in feet per second, H for the difference of level or head in feet, and g for the measure of the accelerating force of gravity, or the number of feet per second at which a falling body is moving at the end of the first second (equal to about 32·2).

Then

$$v = \sqrt{2gH}$$

or

$$v = 8{\cdot}024\ \sqrt{H}$$

If to the natural head (H) be added artificial pressure (H^1), then

$$v = 8{\cdot}024\ \sqrt{H + H^1}$$

The quantity discharged from an orifice is proportional to the area of the opening and the velocity. As the sectional

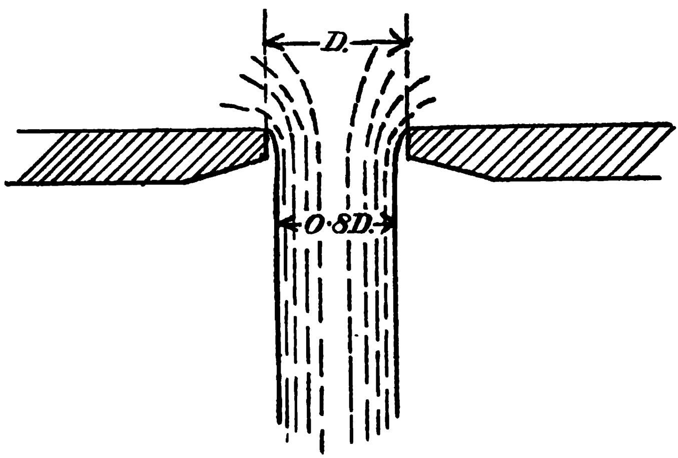


Fig. 1.

area of the jet is less than the area of the orifice, the quantity discharged is not found by multiplying the area of the opening by the velocity, but a coefficient has to be applied to represent the extent of the reduction of the area of the jet (called the Vena Contracta).

If

Q = Discharge in cubic feet per second.
A = Area of the orifice in square feet.
C = A coefficient.

Then

$$Q = C.A \times 8{\cdot}024\ \sqrt{H}$$

The amount of the reduction in the area of the jet, caused by the Vena Contracta, depends upon the shape and the edges

of the orifice. If the orifice is circular, and its inner edge is perfectly sharp, the diameter of the issuing jet will be about 80 per cent. of the diameter of the orifice, or the area of the jet will be about ·64 that of the orifice. The value of the coefficient C in the above expression will be generally less than ·64. This form of jet is shown by Fig. 1.

The following Table gives the results of experiments, with sharp-edged circular orifices, by various observers in the past:—

Experimenter.	Head.	Diameter of Orifice.	Coefficient.
	Feet.	Inch.	
Eytelwein, ...	2·4	1·0	0·618
Bossut, ...	0·6	1·0	0·649
Castel, ...	2·7	1·2	0·629
Venturi, ...	2·9	1·6	0·622
Rennie, ...	1·0	1·0	0·633
,, ...	2·0	1·0	0·619
Weisbach, ...	2·0	1·2	0·614
,, ...	2·0	1·6	0·607
,, ...	0·8	1·2	0·622
,, ...	0·8	1·6	0·614

Experiments were made by the late Mr. James Simpson and Mr. John G. Mair-Rumley, and the results (communicated to the Institution of Civil Engineers) are given in the following Table:—

COEFFICIENTS OF DISCHARGE FROM CIRCULAR ORIFICES.
Temperature 51° to 55° Fahr.

Head. Inches.	Approximate Diameter of Orifice in Inches.								
	1	1¼	1½	1¾	2	2¼	2½	2¾	3
	Absolute Area in Square Feet.								
	0·00546	0·00852	0·012281	0·016749	0·021806	0·027576	0·033898	0·040933	0·049139
	Coefficients.								
9	0·616	0·614	0·616	0·610	0·616	0·612	0·607	0·607	0·609
12	0·613	0·612	0·612	0·611	0·612	0·611	0·604	0·608	0·609
15	0·613	0·614	0·610	0·608	0·612	0·608	0·605	0·605	0·606
18	0·610	0·612	0·611	0·606	0·610	0·607	0·603	0·607	0·605
21	0·612	0·611	0·611	0·605	0·611	0·605	0·604	0·607	0·605
24	0·609	0·613	0·609	0·606	0·609	0·606	0·604	0·604	0·605

Professor Unwin has deduced, from this Table, the following formula for the coefficient of discharge, which is applicable within a limited range:—

$$C = 0{\cdot}6075 + \frac{0{\cdot}0098}{\sqrt{H}} - 0{\cdot}0037D$$

where H is the head in feet, and D is the diameter in inches.

Orifices of this form afford a very convenient method of gauging the flow of water during trials of engines and hydraulic machinery, but the variable coefficient has always been a drawback. With a view to obviate this Mr. Edgar Thrupp has examined the experiments on 37 different orifices with the following results:—

(1) The discharge is not proportional to the square root of H, unless the diameter of the orifice is about 6 inches.

(2) The area of the jet is not proportional to the area of the orifice, but is more nearly proportional to $D^{1{\cdot}98}$ (D being the diameter of the orifice) when H is 1 foot.

If

$$Q = \text{discharge in cubic feet per second,}$$
$$H = \text{head of water in feet,}$$

and

$$D = \text{diameter of orifice in feet,}$$

the following formula is arrived at from the 37 orifices:—

$$Q = 3{\cdot}715\ D^{1{\cdot}98}\ \sqrt[n]{H}$$

and

$$n = 1{\cdot}97 - 0{\cdot}08 \log D.$$

The experiments of Ellis on orifices, 1 foot and 2 feet in diameter, give values of n as about 1·97 and 1·95 respectively, while some of Mr. Thrupp's experiments on orifices less than one-third of an inch in diameter show "n" as high as 2·15.

After determining D, the formula may be simplified to

$$Q = x \cdot \sqrt[n]{H}.$$

As an example, take $D = {\cdot}25$ foot.

Then $n = 2{\cdot}02$ and $x = 2{\cdot}39$ and

$$Q = 2{\cdot}39\ \sqrt[2{\cdot}02]{H}$$

TABLE SHOWING THE DEGREE OF ACCURACY OF THE FORMULA $Q = 3\cdot715\ D^{1\cdot96}\sqrt[n]{H}$ BASED ON 216 EXPERIMENTS ON THE DISCHARGE OF 37 SHARP-EDGED *CIRCULAR ORIFICES.*

NAME OF OBSERVER.	Number of Experiments.	Diameter of Orifice in feet.	Head of Water in feet.		Mean Error of Formula.	
			Maximum.	Minimum.	+ per cent.	− per cent.
Ellis, . . .	7	2·0	9·64	1·77	...	− 1·70
Hamilton-Smith,	1	1·01	1·05	1·05	...	− 2·00
Ellis, . . .	10	1·00	17·72	1·15	+ 1·43	...
Hamilton-Smith,	1	0·66	1·09	1·09	+ 0·28	...
Michelotti, . .	2	0·53	12·0	6·9	...	− 0·71
Ellis, . . .	13	0·50	17·26	2·15	...	− 0·28
Hamilton-Smith,	1	0·419	1·20	1·20	...	− 0·45
Michelotti, . .	1	0·270	12·50	12·50	...	− 1·96
Hamilton-Smith,	1	0·253	1·33	1·33	...	− 1·51
Mair-Rumley, .	6	0·2501	2·00	0·75	...	− 0·19
,, . .	6	0·2283	2·00	0·75	0·00	− 0·00
,, . .	6	0·2078	2·00	0·75	+ 0·47	...
,, . .	6	0·1874	2·00	0·75	+ 0·36	...
Michelotti, . .	1	0·18	7·20	7·28	...	− 0·91
Bossut, . .	1	0·178	12·50	12·50	...	− 3·10
Mair-Rumley, .	6	0·1666	2·00	0·75	...	− 0·32
,, . .	6	0·1460	2·00	0·75	+ 0·56	...
Weisbach, . .	2	0·13	2·00	0·82	+ 1·45	...
Mair-Rumley, .	6	0·1250	2·00	0·75	+ 0·21	...
,, . .	6	0·1041	2·00	0·75	+ 0·34	...
Hamilton-Smith,	19	0·10	4·62	0·129	+ 1·05	...
Weisbach, . .	2	0·10	2·00	0·82	...	− 0·42
Bossut, . .	1	0·089	12·50	12·50	...	− 3·00
Mair-Rumley, .	6	0·0834	2·00	0·75	+ 0·83	...
Weisbach, . .	2	0·066	2·00	0·82	...	− 0·79
Hamilton-Smith,	21	0·0498	4·63	0·185	+ 0·42	...
Bossut, . .	1	0·044	12·50	12·50	...	− 2·48
Weisbach, . .	7	0·033	340·0	0·066	...	− 4·23
Steckel, . .	3	0·032	4·2	1·00	...	− 0·74
Thrupp, . .	4	0·02783	1·416	0·583	...	− 3·63
,, . .	6	0·02758	1·50	0·475	...	− 4·17
,, . .	14	0·02700	1·75	0·527	...	− 3·78
,, . .	11	0·0212	1·75	0·458	...	− 3·36
Hamilton-Smith,	3	0·020	3·19	0·739	...	− 1·11
Thrupp, . .	9	0·0185	1·75	0·518	+ 3·24	...
,, . .	8	0·0148	1·75	0·500	...	− 3·94
,, . .	10	0·00925	1·708	0·496	+ 4·00	...
Total— 37 Orifices.	216 Experiments.		340·0	0·606		
			Extremes.			

The error per cent. is called "plus" when the formula gives more than the observed discharge.

The above shows a mean error of minus 0·82 per cent. Omitting the last 11 orifices (in which slight errors in the measurement of the diameter largely affect the results), the remaining 26 orifices show a mean error of only minus 0·38 per cent.

From the above Table it appears that if results are required within 0·5 per cent., the orifice must be tested to obtain its coefficient "x."

The temperature of water has a slight effect upon the co-

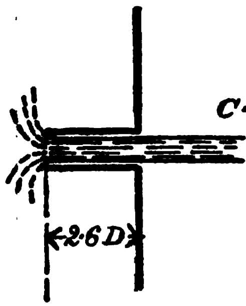


Fig. 2.

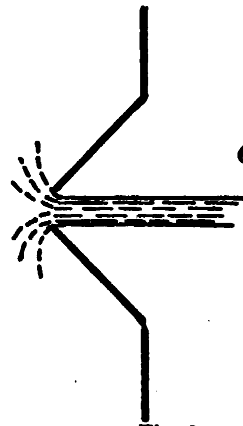


Fig. 3.

efficient of discharge from an orifice. Experiments made by Mr. Mair-Rumley show that with a sharp-edged orifice $2\frac{1}{4}$ inches

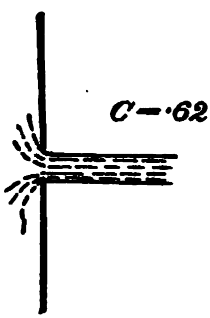


Fig. 4.

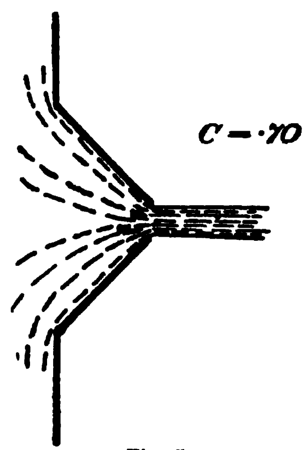


Fig. 5.

in diameter, and with a head of 21 inches, the coefficient C was ·604 for temperatures varying from 57° up to 110°, and increased to ·607 for temperatures up to 179°.

The accompanying figures show the effect of the shape of the outlet upon the coefficient of discharge C in the formula

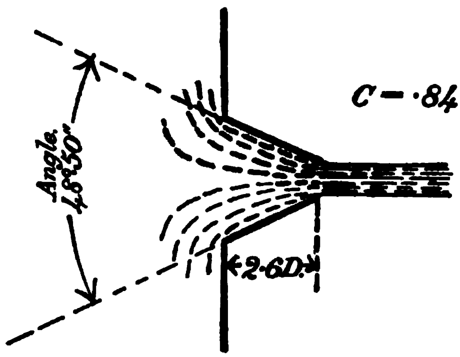


Fig. 6.

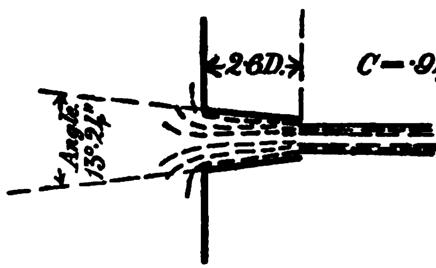


Fig. 7.

$Q = C A \times 8{\cdot}024 \sqrt{H}$:—The greatest contraction of the jet occurs with a short tube projecting into the vessel (Fig. 2),

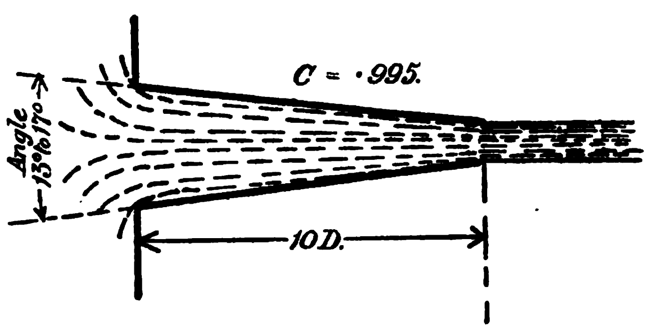


Fig. 8.

giving a coefficient of ·52. Fig. 4 shows the sharp-edged orifice in a flat plate, as in Fig. 1. Figs. 6, 7, 9, and 10 are

from Castel's experiments. In Fig. 10 the coefficient ·829 only applies in case the short tube projecting out of the

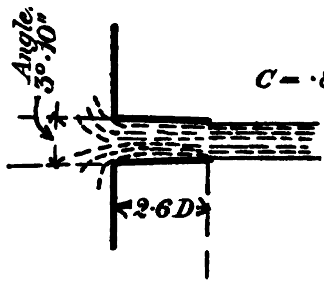


Fig. 9.

vessel runs full at the outlet, as it generally does; but if the jet escapes without touching the sides of the tube, and

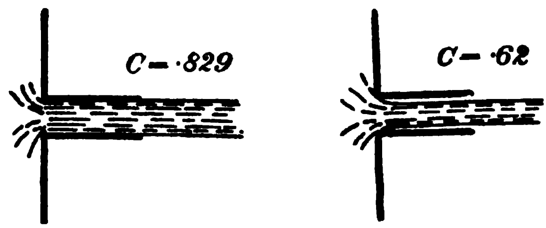


Fig. 10.

the internal edge is perfectly rectangular, the coefficient will be reduced to ·62. Fig. 8 is from the experiments of Mr.

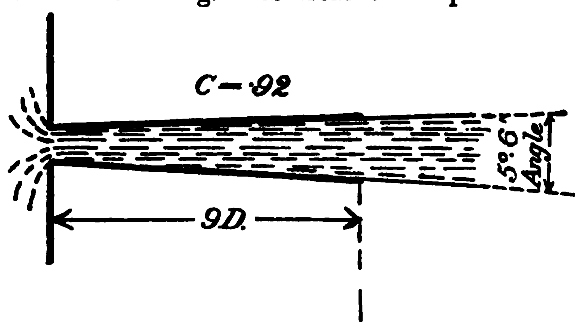


Fig. 11.

Hamilton-Smith, jun., on the nozzles used in California for directing a jet of water against the working faces in gold mines under a head of over 300 feet. Fig. 11 is from Venturi's

experiments with divergent mouthpieces, which showed that the discharge of an orifice could be increased by placing a cone of this description on the outlet. The greatest increase was found with an angle of divergence of 5° 6′ in a cone having a length of nine times the diameter of the orifice. The increase

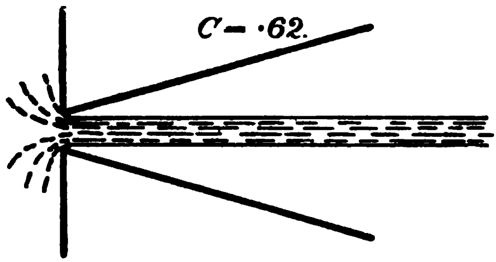


Fig. 12.

is due to the fact that the velocity of the water after passing through the orifice is gradually reduced before the free discharge takes place, and the head due to this reduction of velocity assists the statical head upon the orifice. This discovery is of

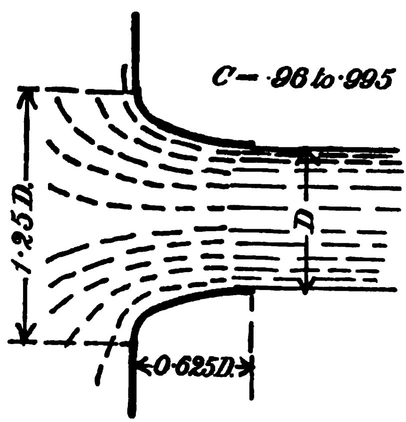


Fig. 13.

great practical value. If, however, the divergence is too great, as in Fig. 12, the advantage is lost. Fig. 13 shows what is called a "conoidal orifice," which is shaped to correspond with the natural form of a jet from a sharp-edged orifice, with the result that the coefficient reaches from ·96 to ·995. In all the

cases where the outlet is tapered the diameter is measured at the narrowest part. The sharp-edged orifice in a flat plate is the easiest form to reproduce, and gives results, for any given diameter and head, as uniform as any other kind of orifice, and is, therefore, the most suitable for accurate gauging purposes.

WEIRS.

Gauging Water by Weirs.

For gauging running water it is often more convenient to use a sharp-edged weir instead of an orifice, particularly for large volumes flowing in open channels. The theoretical formula for the flow over a weir is

$$Q = C\,l\,H + \tfrac{2}{3}\,\sqrt{2gH}$$

Where

Q = discharge in cubic feet per second.
l = length of weir in feet.
H = head of water in feet.
C = a coefficient.

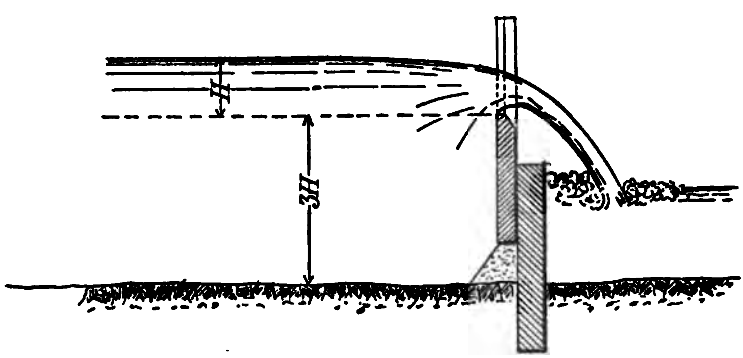


Fig. 14.

The head is measured from the level of the edge or sill of the weir to the level of the surface of the water, a short distance up stream, at a point sufficiently removed from the

weir to avoid the curve of the surface approaching the overfall (see Fig. 14).

The coefficient C is found to be about the same as that for sharp-edged orifices, namely, ·62, but it varies with the head, and with the length of the weir. It is also affected by the size of the channel approaching the weir. If the depth of water behind the weir is at least $4\,H$, and if the channel extends at least $3\,H$ beyond the end of the weir at the level of the sill, then the contraction is said to be "complete," and the velocity of approach will be insignificant. For accurate gaugings these conditions should be fulfilled. When the channel is smaller, an allowance has to be made for the head due to the velocity of approach, by adding the latter head to the observed head. The effective head is then $H + \frac{v^2}{2g}$, where v is the velocity of approach. When v is less than ·25 feet per second it may be neglected.

By substituting 8·024 for $\sqrt{2g}$ and taking $C = \cdot 62$ the formula becomes

$$Q = 3\cdot316\ l\,H^{1\cdot5}$$

This does not provide for the variations in the coefficient. Mr. Thrupp has arrived at the following modification of the formula to avoid the necessity for a table of coefficients.

$$Q = 3\cdot112\ H^{1\cdot48}\,l^{1\cdot001 + \cdot02 \log l}.$$

When the length of the weir has been measured, the formula for that weir can be reduced to the form

$$Q = m\,H^{1\cdot48}$$

Where

$$m = 3\cdot112\,l^{1\cdot001 + \cdot02 \log l}$$

If $l = 1$ foot, then

$$Q = 3\cdot112\ H^{1\cdot48}.$$

Again, if $l = 3\cdot5$ feet, then

$$Q = 3\cdot112\ H^{1\cdot48}\ 3\cdot5^{1\cdot0119}$$
$$= 11\cdot056\ H^{1\cdot48}$$

TABLE SHOWING THE DEGREE OF ACCURACY OF THE FORMULA $Q = 3{\cdot}112\, H^{1{\cdot}48}\, l^{1{\cdot}001 + {\cdot}02 \log l}$ BASED ON 163 EXPERIMENTS ON 22 WEIRS.

Names of Observers.	Length of weir in feet.	Number of Experiments.	Head of Water in feet. Maximum.	Head of Water in feet. Minimum.	Mean error per cent. +	Mean error per cent. -
Castel,	0·0328	5	0·6526	0·3947	...	− 3·36
,,	0·0653	10	0·7869	0·2008	...	− 2·37
,,	0·0988	9	0·6550	0·1627	...	− 1·17
Donkin & Salter,	0·1250	12	0·2500	0·0416	+ 1·17	...
J. Goodman,	0·1458	11	0·1815	0·1620	+ 0·76	...
Castel,	0·1637	12	0·7962	0·1303	...	− 0·56
,,	0·3294	13	0·7898	0·0991	+ 0·91	...
,,	0·6542	11	0·6817	0·0994	...	− 0·39
Poncelet & Lebros,	0·6562	12	0·6821	0·0771	...	− 0·72
Castel,	0·9849	8	0·4562	0·1038	...	− 1·53
Thrupp,	1·000	9	0·1708	0·1266	...	− 0·33
Francis,	1·829	1	1·0627	1·0627	+ 0·35	...
Fteley & Stearns,	2·3125	3	0·9568	0·7478	...	− 1·10
Hamilton-Smith,	2·586	12	1·7327	0·5659	...	− 1·04
Fteley & Stearns,	3·008	5	0·7416	0·2156	...	− 2·10
Francis,	3·500	4	1·0656	0·5085	...	− 0·32
,,	3·9985	2	1·0202	0·6830	...	− 0·79
,,	5·487	2	1·1336	0·4936	...	− 0·47
,,	6·987	5	0·9554	0·3146	...	− 0·47
,,	8·489	2	0·8361	0·3662	+ 0·19	...
,,	9·997	8	1·5598	0·6536	+ 0·18	...
Thrupp,	10·000	7	0·1625	0·125	...	− 0·66

$\underbrace{1{\cdot}7327 \quad 0{\cdot}0416}_{\text{Extremes.}}$

Mean error for 22 weirs = minus 0·628 °/。

Mean error for last 18 weirs = minus 0·45 °/。

The error per cent. is called "plus" when the formula gives more than the observed discharge.

The excess of "minus" errors may be attributed to slight rounding of edges. If the cases in which the error exceeds 1 per cent. be omitted, there remain 14 sets of experiments showing a mean error of only − ·166 per cent.

FLOW OF WATER THROUGH PIPES.

Water flowing through a pipe or channel has to overcome the friction caused by its movement along the interior surface of the pipe or the bed of the channel. The amount of the

friction is measured by the force that is necessary to overcome it. In a conduit of uniform section, this force is the head or loss of pressure ("h") in a given length ("l") multiplied by the sectional area of the conduit (A).

In an open channel "h" is represented by the fall of the surface line (Fig. 15), the slope of which is called the "hydraulic

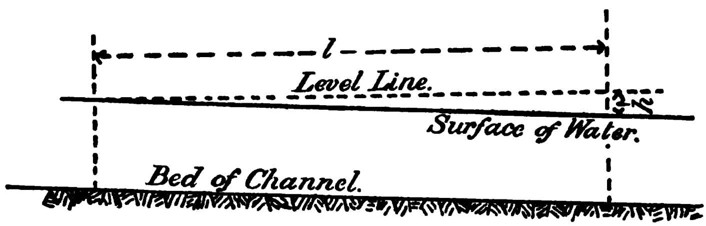


Fig. 15.

gradient." In the case of a pipe running full under pressure (Fig. 16), "h" is the difference of the levels to which the water would rise in similar branch pipes, open at the top and placed at each end of the length "l." If the water is at rest in the

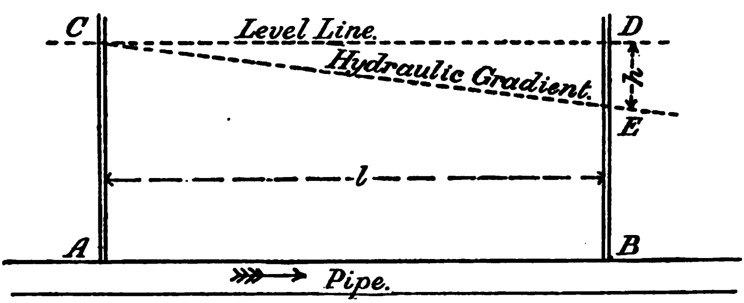


Fig. 16.

pipe the level will be the same at the points C and D, but if there is a flow from A to B, then the level at D will fall below that at C, and the line $C\,E$ represents this hydraulic gradient.

At small velocities "h" is found to be roughly in simple proportion to the mean velocity v, but at higher velocities "h" varies in proportion to $v^{1{\cdot}70}$ to v^2 according to the nature of the surface of the conduit. The smoother the surface the lower the index of v.

The nature of the surface is found to have a large influence upon "h," independent of its effect upon the index of v. The temperature also has an influence on the discharge.

It has been said that the moving force is $h \times A$; A being the sectional area of the conduit which is filled with water. The resulting mean velocity depends not only on the nature, but also on the area, of the surface in contact with the water, the area being a multiple of "l." This multiple is called the "wetted perimeter" (P). In the case of a pipe, P is the circumference of a circle having the same diameter as the inside of the pipe. It follows, theoretically, that v is in some way proportional to $\frac{h \times A}{l \times P}$. For convenience it is preferable to divide l by h to obtain the cosecant of the angle of inclination of the hydraulic gradient (S), and to divide A by P to obtain a factor representing the shape and size of the conduit which is called the "hydraulic radius" (R). This, although only a theoretical factor, serves its purpose remarkably well, except in the case of wide and shallow open channels with very irregular beds.

It may, therefore, be stated that the mean velocity v is *in some way*—

1st, directly proportional to R $\left(\text{or } \frac{A}{P}\right)$;

2nd, inversely proportional to S $\left(\text{or } \frac{l}{h}\right)$;

3rd, inversely proportional to the roughness of the surface;

4th, directly proportional to the temperature.

The actual proportions can only be arrived at by experiment. No general theory has yet been advanced which covers the whole range of conditions that occur in practice, so it is necessary to use different coefficients or constants to meet the circumstances of the case. The simplest form of equation which can be easily adapted to suit the various conditions is Mr. Thrupp's modification of Dr. G. Hagen's formula, and is as follows:—

(1) $$v = \frac{R^x}{C \sqrt[n]{S}} \times \left(1 + \frac{T - 50}{K}\right)$$

v = the mean velocity in feet per second.
R = the hydraulic radius in feet.
S = the cosecant of the angle of inclination of the hydraulic gradient $= \frac{\text{length}}{\text{head}}$.
C = a coefficient (representing the roughness of the surface).
T = the temperature of the water in degrees Fahrenheit.

The index "x" and the root "n," as well as the coefficient "C," depend on the nature of the surface; they have distinct values for velocities above and below what is called the "critical velocity," which is referred to more fully hereafter.

"K" is the temperature coefficient which has only two values: 600 above the critical velocity and 200 below that velocity.

(If the velocity were simply proportional to the absolute temperature, "K" would be 510 or 460 + 50, as the coefficients "C," given in the Table on p. 16, are worked out to apply to a temperature of 50° Fahr., so that for many practical purposes the "temperature coefficient" may be neglected.)

Below the critical velocity "n" may be taken as 1·00, "K" as 200, and "x" as 1·70, thus reducing the equation (1) to the form

(2) $$v = \frac{R^{1\cdot70}}{C\,S} \times \left(1 + \frac{T - 50}{200}\right)$$

In dealing with the flow of water through pipes, it is generally more convenient to use a formula for discharge instead of for velocity.

If

Q = discharge in cubic feet per second,
D = diameter of pipe in feet,

and

P = coefficient in place of "C,"

(3) $$Q = \frac{D^{2+x}}{P \sqrt[n]{S}} \times \left(1 + \frac{T - 50}{600}\right)$$

for velocities above the critical point; and

(4) $$Q = \frac{D^{3.7}}{P\ S} \times \left(1 + \frac{T - 50}{200}\right)$$

for velocities below the critical point. The coefficient "P" in equation (3) is related to "C" in equation (1) thus—

$$P = C \times \frac{7}{88} \times 4^{(2+x)}$$

The 2 added to "x" in the index of "D" is derived from the variation of the area in proportion to the square of the diameter.

Table of Coefficients relating to Equation No. 1, p. 15, and Equation No. 3, p. 16, and applicable for Velocities more than 20 per cent. greater than the Critical Velocity.

Factor to which the coefficient relates.	Velocity.	Roughness.	Hydraulic Radius.	Temperature.	Roughness.
Description of surfaces.	n	C Formula No. 1.	x	K	P Formula No. 3.
Lead, Tin, Copper, &c., .	1·75	0·005224	0·62	600	·015704
Cast Iron, new, . A,	1·85	0·005347	0·67	600	·01723
Cast Iron, new, . B*,	2·00	0·006752	0·63	600	·020584
Old Cast Iron, ...	2·00	0·017115	0·66	600	·03353
Ditto cleaned, ...	1·95	0·0074191	0·64	600	·02293
Wrought Iron, new, . .	1·80	0·004787	0·65†	600	·015002
Rivetted Sheet Iron, . .	1·825	0·005674	0·677	600	·018459
Pure Cement rendering, A,	1·74	0·004000	0·67	600	·012891
Pure Cement rendering, . . B*,	1·95	0·006429	0·61	600	·019061
Brickwork, in good condition, ...	2·00	0·007746	0·61	600	·022965

* Other coefficients will be found in the *Transactions of the Society of Engineers* for December, 1887. Those given in the above Table have been slightly altered to refer to a temperature of 50° F. For high velocities the set of coefficients marked B should be used, and for medium velocities the set marked A. Whichever set gives the lowest velocity is the correct one to use.

† For pipes less than ·28 foot diameter, when great accuracy is required, take $x = \cdot 65 + \cdot 018\sqrt{\frac{\cdot 28 - D}{D}}$.

When the velocity "v," or the discharge "Q," by equations

(1) or (3) work out higher than by equations (2) or (4), the latter are the correct ones to use. When they work out the same, the velocity is a little below the critical velocity, and equations Nos. 2 and 4 will hold good up to a point at which they give "v" or "Q" about 25 per cent. higher than equations 1 or 3. This is the "Critical Point," where the value of "n" suddenly changes from 1·00 to about 4·00. At all velocities more than 20 per cent. higher than the critical velocity equations 1 and 3 hold good.

Putting it another way:—When equations (2) and (4) give results from 25 to 50 per cent. higher than (1) and (3), the conditions are in the critical region where "n" = 4·00. At higher velocities (1) and (3) hold good, and at lower velocities (2) and (4) hold good.

The coefficients relating to Equation No. 4 appear to differ very slightly from one another for pipes of the same size. Taking $n = 1$ and $x = 1·70$; P comes out at ·00005 for lead pipes and ·000046 for wrought-iron pipes. For pipes between $\frac{1}{4}$ of an inch and 3 inches in diameter, the formula may be taken as

$$Q = \frac{D^{37}}{·00005 \times S}\left(1 + \frac{T - 50}{200}\right)$$

This has been used in plotting the portion of Plate I., which refers to the region below the critical point. The index of D bears some kind of inverse proportion to D, reaching a maximum value of about 4 for very small tubes.

The phenomenon of the sudden change in the value of "n" at the critical velocity has been investigated by Professor Osborne Reynolds.

It has been generally considered that if a body of water is passing through a pipe in lines or threads parallel to each other, it will continue to do so, provided no change of shape or interruption is caused in the pipe. Professor Osborne Reynolds has, however, shown in a paper published in the *Philosophical Transactions*, that beyond a certain velocity (which he terms "critical velocity") the fluid ceases to flow

in parallel lines, and suddenly bursts into eddies, a viscous fluid being less liable to form eddies than a non-viscous fluid, and an increase in temperature increasing the tendency to form eddies. This change of a steady motion into an unstable or sinuous motion is of the greatest interest and importance.

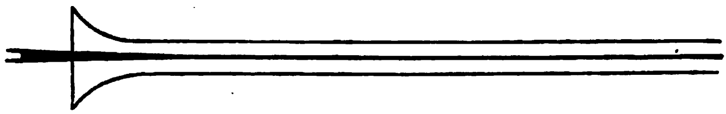


Fig. 17.

No apparent definition had previously been made of the point at which this change of law occurred, or as to the circumstances which produced the change from steady to unsteady motion, that is, from motion in parallel lines to motion in sinuous or eddying lines.

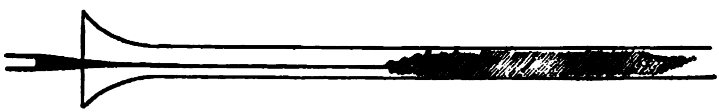


Fig. 18.

Professor Reynolds' experiments were made with glass tubes about 4 feet 6 inches in length, and 1-inch, ½-inch, ¼-inch diameter, with trumpet-shaped mouths. They were arranged so as to be able to draw water out of a large glass tank in which they were immersed, whilst a streak of coloured water

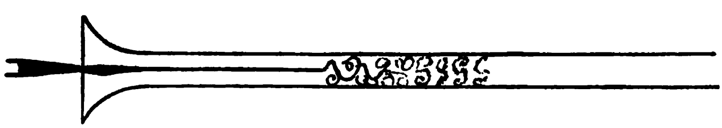


Fig. 19.

was admitted at the point of inflow of water into the pipe. Fig. 17 shows the result when the velocities were low, the coloured streak continuing in a straight line. As the velocity was increased, a point was reached when the coloured streak would suddenly break up and become mixed with the clear water, as shown by Fig. 18. As the velocity increased, the

point at which the break-up occurred approached the trumpet mouth. By the aid of the electric spark, the eddying or curling appearance of the coloured water was made apparent, as shown in Fig 19. It was found that the velocity at which the junction of eddies occurred was almost exactly in the inverse ratio of the diameter of the tubes, and that the critical velocity diminished as the temperature rose.

Further experiments were made with water flowing in two straight lead pipes, each 16 feet long and ½-inch and ¼-inch in diameter. Gauge holes were made 10 feet and 15 feet apart in these pipes to measure the head "h" as indicated in Fig. 16, p. 13, and the results proved that at lower velocities the head was proportional to the velocity, and that the velocities at which a deviation from the law first occurred were in exact inverse ratio of the diameters of the pipes. Also, that when a velocity equal to the critical velocity multiplied by 1·2 was reached, the pressure did not vary as the square of the velocity, but as 1·722 power of the velocity.

Although the critical velocities in Prof. Reynolds' experiments were found to be in exact inverse ratio of the diameters, the same rule does not hold for pipes of larger diameter. The following Table shows this:—

TABLE OF OBSERVED "CRITICAL VELOCITIES."

Description of Pipe.	Diameter of pipe in inches.	Temperature in degrees Fahr.	Approximate critical velocity in feet per sec.	Name of Observer.
Lead, ...	0·242	48·2°	1·45	Osborne Reynolds.
"	0·498	46·4°	0·74	" "
"	0·549	?	0·541	Darcy.
Tin, ...	1·06	?	0·322	Dubuat.
Lead, ...	2·5	?	0·22	J. Leslie.
Wrought iron, .	0·48	70°	0·38	Darcy.
" " .	0·49	54·5°	1·39	Thrupp.
" " .	1·057	52·6°	0·302	Darcy.
Cast iron, . .	15·0	40° to 45°	0·445	Thrupp.

The effect of high pressures upon the viscosity of water is extremely small and differs with the temperature. Mr. R.

Cohen has made some experiments on the flow of water through a very small tube. He observed the time required for discharging a given quantity of water through the tube with the same working "head," but with the whole apparatus placed under various pressures and temperatures, and he found that the time required was reduced, as the pressure increased, by the amounts indicated in the following table:—

Pressure in Atmospheres.	300	600	900
Temperature Centigrade.	Reduction of time—per cent.		
1°	3·82	6·28	...
15°	1·49	2·33	2·76
23°	0·76	1·01	...

From these observations it would appear that at about 30° Centigrade (86° Fahr.) the friction of water is not affected by pressure at all, and at higher temperatures the friction would be increased by pressure.

The velocities in these experiments were no doubt below the critical point. At velocities above the critical point (*i.e.*, under ordinary working conditions) the effect of pressure upon the friction would probably be even less than that observed by Mr. Cohen.

Water in entering a pipe is subjected to a loss of pressure corresponding to the head required to produce the velocity at which it moves along the pipe. The loss of head can never be less than $\frac{v^2}{2g}$; but it may be more if the entrance to the pipe is not bell-mouthed or tapered. If, for instance, the entrance is square-edged, as in the orifice, Fig. 10, p. 8, the loss will be $\frac{v^2}{2g \times \cdot 62}$ or $1 \cdot 6 \times \frac{v^2}{2g}$. This will represent the loss in the case of water entering the square-edged ports of an engine slide valve.

If the mouthpiece is similiar to orifice, Fig. 13, p. 9, the loss would be only $1{\cdot}01\,\frac{v^2}{2g}$ to $1{\cdot}04\,\frac{v^2}{2g}$.

In the case of a sudden change of diameter in a pipe, as in Fig. 20, with a square edge at the mouth of the small pipe,

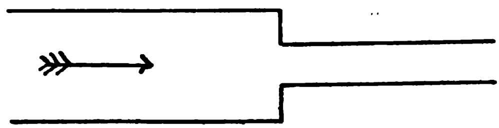


Fig. 20.

if v is the velocity in the large pipe, and V that in the small pipe, the loss due to the change of velocity will be $1{\cdot}6\,\frac{(V-v)^2}{2g}$.

With a gradual reduction of diameter the loss may be reduced to $1{\cdot}01\,\frac{(V-v)^2}{2g}$.

Taking the flow in the other direction there should be a rise of pressure, theoretically; and if the enlargement is gradual

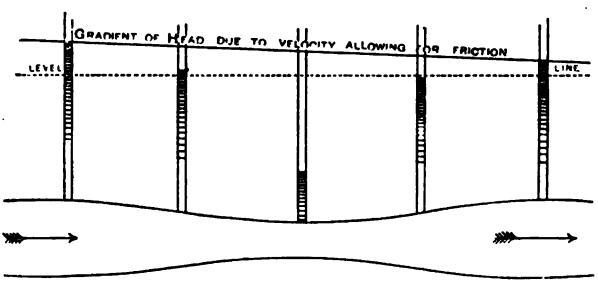


Fig. 21.

with an angle of divergence similar to that of the mouthpiece to orifice on Fig. 11, p. 8, it is found that a rise of pressure actually does take place. Mr. Froude was the first to observe this. He prepared a pipe having gradual changes in diameter, as in Fig. 21; and found that the water did not rise in the branches up to the line of the Hydraulic gradient indicated by the gauges fixed at the wide parts, but fell rapidly where the

pipe contracted, and rose again as it diverged, the maximum depression representing the head due to the increase in the velocity of the water in passing from the widest to the narrowest part of the pipe. Mr. Clemens Herschel has utilised this phenomenon for measuring large volumes of water in what he calls the "Venturi" water meter. He observes the pressure at the narrowest part of a specially constructed contraction in a pipe, and also that in the pipe on each side, and calculates the velocity from the observed depression in the hydraulic gradient.

A sudden enlargement in a pipe does not permit the water to raise the pressure in reducing its velocity, as eddies are set up which absorb the whole of the kinetic energy in friction instead of converting it into pressure energy.

A similar loss of power occurs when flowing water passes round a sharp bend or angle, or when it is subjected to any sudden change of the direction of its movement. In flowing round easy bends in pipes there is practically no loss from this cause, but with sharp bends or elbows the loss may be anything up to about $\frac{v^2}{g}$.

These facts point to the necessity of avoiding, as far as possible, all sharp-edged inlets to ports, and also sharp angles and bends. The best results will be obtained when water passages are designed so as to make all the changes of direction and velocity as gradual as possible.

Plates 1, 2, and 3 show the gradients, discharges, and velocities in various sized pipes and circular culverts, and also the velocities for various values of "*R*" in equations (1) and (3) on pp. 15 and 16. The horizontal scale represents the logarithms of "*S*," and the vertical scale the logarithms of "*Q*."

One set of sloping lines refers to particular sizes of pipes or values of "*R*," and the other set of sloping lines refers to particular velocities. The advantages of this form of diagram are that the lines are generally straight instead of curved,

R IN SMOOTH PIPES.

TIN, COPPER &c.)

the equations:—

$$\frac{D^{2\cdot 62}}{0157\sqrt[1\cdot 75]{S}}\left(1+\frac{T-50}{600}\right)$$

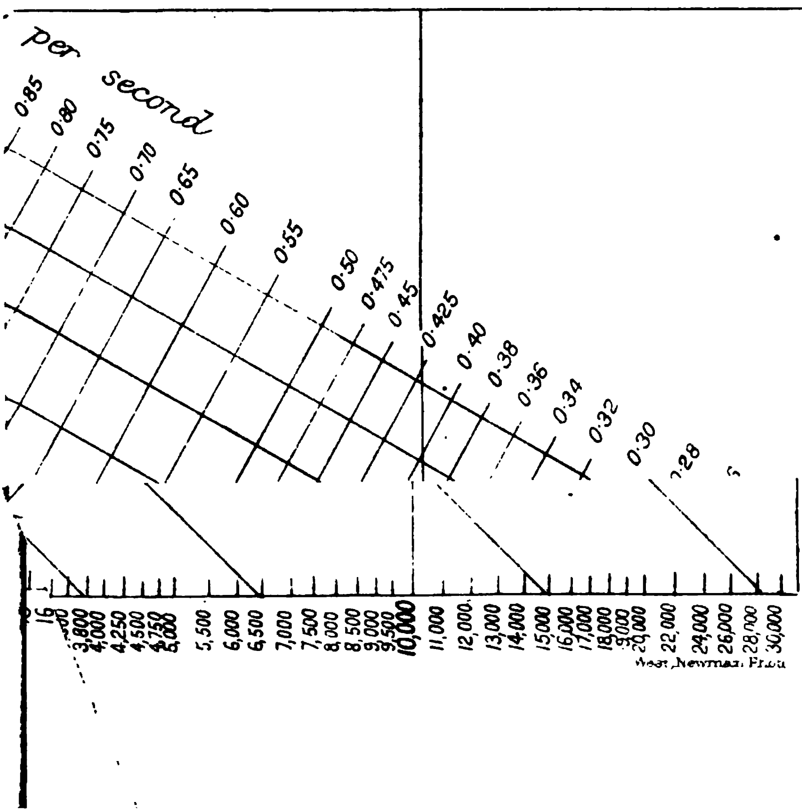
$$\frac{D^{3\cdot 7}}{\cdot 00005\times S}\left(1+\frac{T-50}{200}\right)$$

taking T — 50 (degrees Fahrenheit)

Q — discharge in cubic feet per second.

S — { cosecant of slope or the length of pipe divided by the "head."

D — diameter of pipe in feet.



West, Newman Proc

ST IRON PIPES.

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cond

$$\left(1 + \frac{T-50}{600}\right)$$

s over 6·5 feet per second

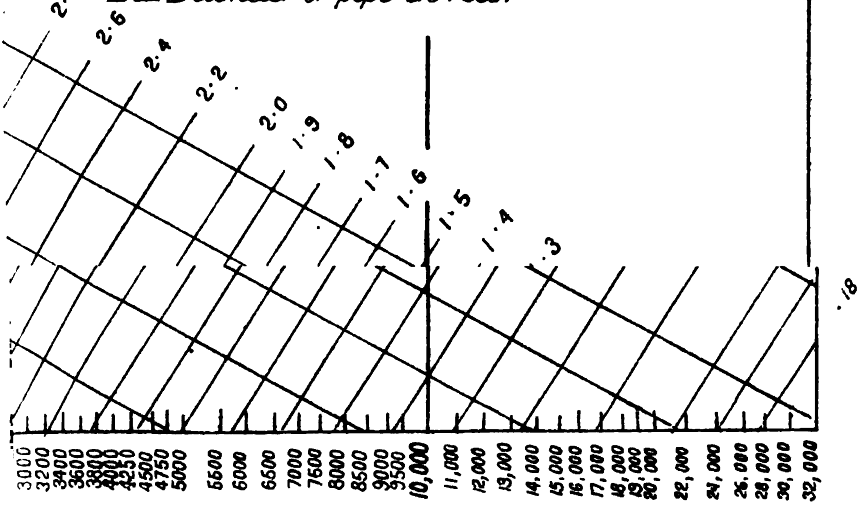
$$Q = \frac{D^{2\cdot 63}}{\cdot 0209\sqrt{S}}\left(1 + \frac{T-50}{600}\right)$$

T is taken at 50° Fahrenheit

Q — Discharge in cubic feet per sec.

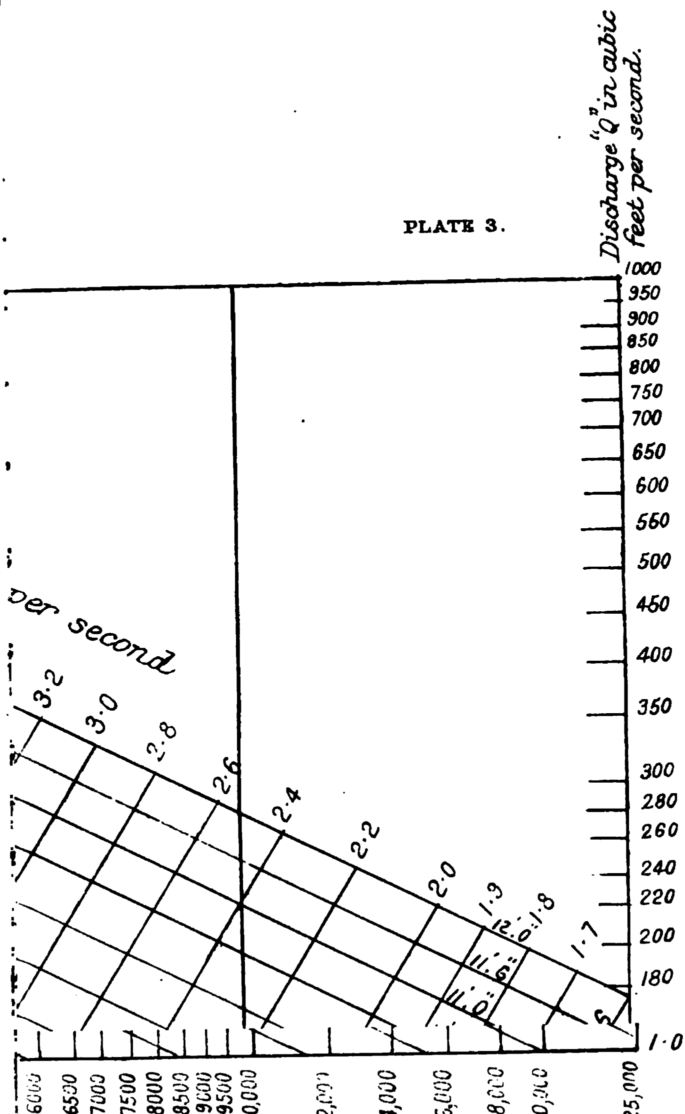
S — {Cosecant of slope or length of pipe divided by the head.

D — Diameter of pipe in feet.



West, Newman Photo.

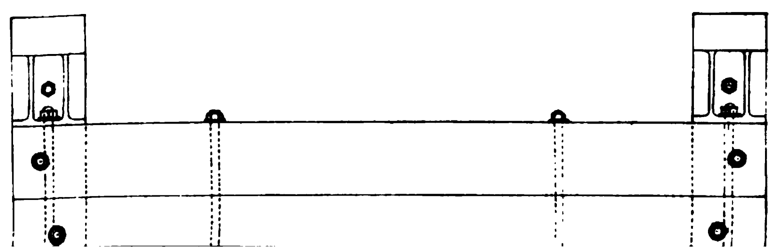
PLATE 3.

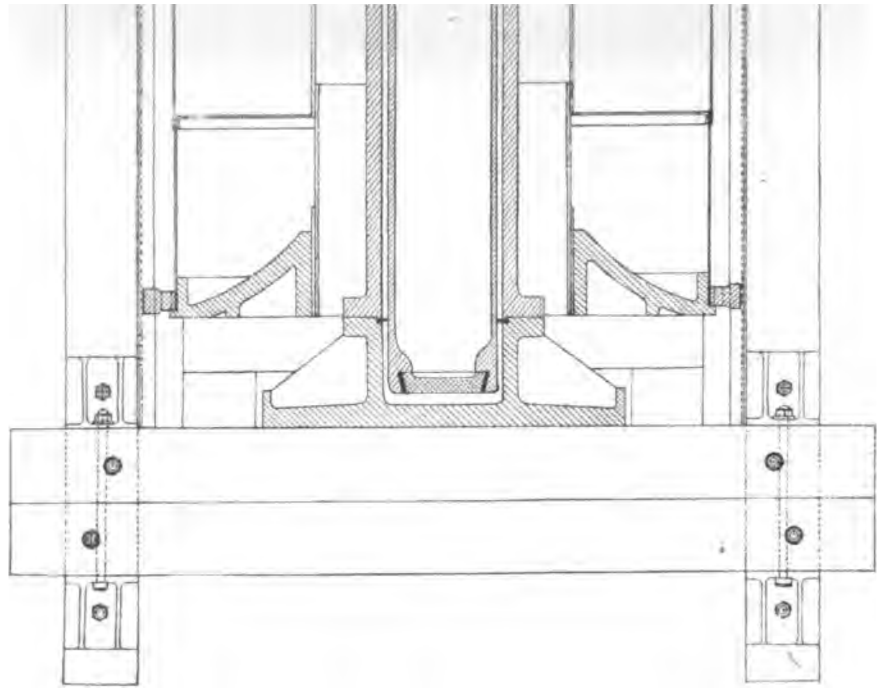


West, Newman lith.

ARMSTRONG ACCUMULATOR.

PLATE 4.





VERTICAL SECTION.

West, Newman Photo.

and the results can be read off with exactly the same degree of accuracy from all parts of the diagram, which covers a range of conditions far greater than could be represented in the same space if the natural numbers were plotted.

The natural numbers are written against the lines representing their logarithms, on the vertical and horizontal scales.

Example.—On Plate 1 the spot marked x gives the following coincident values of the various factors :—

$S = 113$ Q (discharge of a pipe) $= \cdot 0395$ cubic ft. per sec.
$v = 1\cdot 9$ ft. per second.
$D = \cdot 166$ ft. $= 2$ ins. diameter.

The diagrams all refer to a temperature of 50° F. For accurate results at other temperatures multiply v or Q by $\left(1 + \frac{T - 50}{K}\right)$.

THE ACCUMULATOR.

Lord Armstrong devised the Accumulator as a means of obtaining pressure on a column of water by a weight instead of by elevation. Plate 4 shows one of the ordinary Armstrong accumulators. The cylinder contains a ram, upon the top of which is attached a crosshead to which is suspended a loaded case. The weight placed in the case can be varied to suit the pressure required, and as the weight rests on the top of the ram it follows that whatever water is pumped into the cylinder from the engine will be subject to that pressure. A stop valve enables the water to be cut off. When the ram has risen to the top of the stroke (and the cylinder is full of water under pressure), it stops the engine by means of a chain connecting with the steam throttle valve of the engine, and water ceases to be pumped

into the accumulator. When the ram falls (owing to the abstraction of water from the cylinder), the steam throttle valve is opened, the engine works again, and water is pumped into the accumulator.

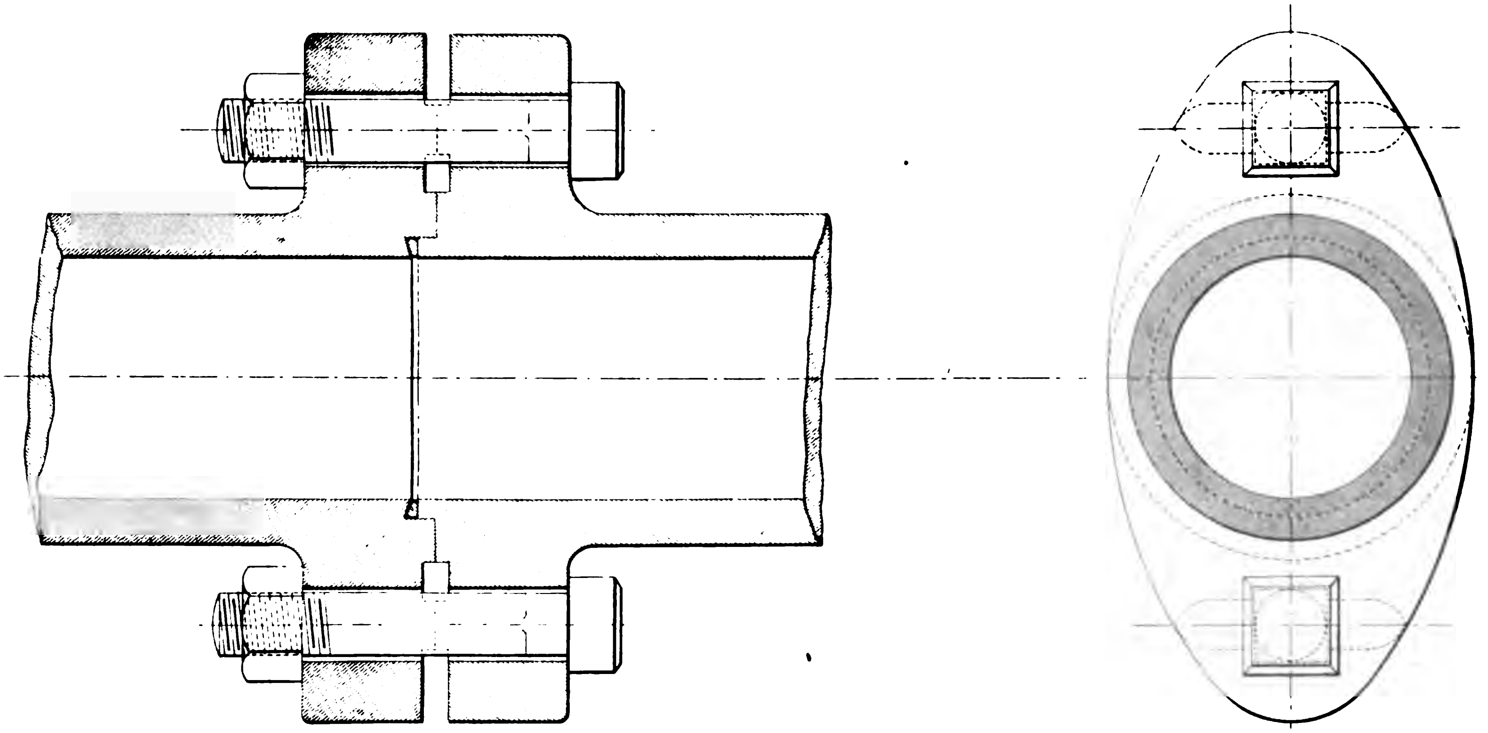
The pressure that has been adopted for transmission through mains, in order to work ordinary hydraulic machines, is about 700 lbs. per square inch. This is found to be a convenient working pressure, both as regards the size and proportions of the working parts and the tightness of joints and valves.

The best way of jointing hydraulic pipes has been the subject of much practical experiment. A guttapercha ring has been adopted as the best means of preserving the joint watertight. Where hydraulic mains are exposed to heat the guttapercha ring will not answer and leather is employed instead. Plate 5 shows a high-pressure flange joint for a 5-inch pipe.

Mr. Ellington has designed a modified form of this joint by putting a projection on the pipe beyond the flange, the spigot and faucet being formed on this projection. The effect is to increase the depth and the strength of the flange, without an increase of its section at the junction between the flange and the pipe.

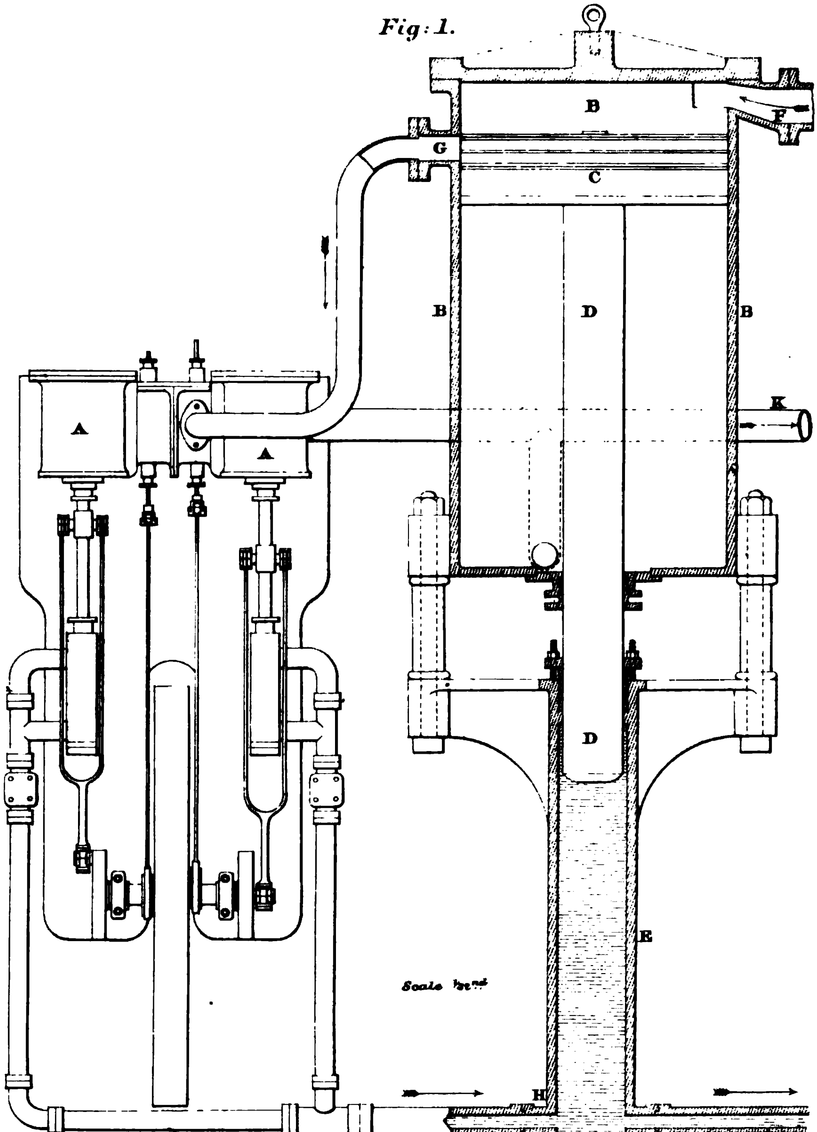
By means of an accumulator an artificial head can be maintained at any part of an hydraulic main. The abstraction of the high-pressure water to actuate hydraulic appliances is practically intermittent. The supply of high-pressure water from the pumping-engine can be continuous. It follows, therefore, that as the transmission of pressure through a water main is practically instantaneous, the intervals (however small) between the time of the production of the power and its utilisation in the appliance, enable the pressure to be maintained, and the excess to be stored in the accumulator. The variation in the consumption of the power, by reason of the fluctuation in the working of the machines, is at once adjusted by the accumulator, which both serves to store up

JOINT FOR 5 INCH PRESSURE PIPE.



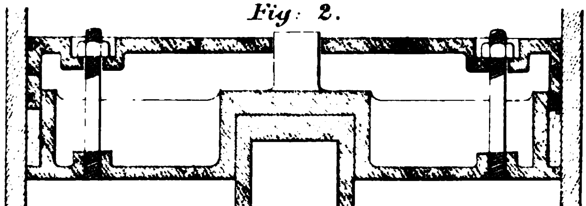
West, Newman Photo

Fig: 1.



SECTIONAL PLAN.

Fig: 2.



SECTION OF PISTON.

Scale 1/16th

Thos Kell & Son, Lith.

the excess of power delivered to the mains from the engines, and also to maintain the pressure in the mains. By this means power is transmitted without practical loss in hydraulic mains. An experiment is recorded as having been carried out on the 6-inch mains of the London Hydraulic Power Company when the main valves were set so that two accumulators differently loaded (the difference being 20 feet head) were at the ends of a circuit of ·5 miles. The lighter accumulator was lowered and shut off, the heavier remaining at the top of its stroke. The lighter accumulator was then turned on, and it was raised by the heavier one.

The amount of energy which is stored up in an accumulator when the ram is at the top of the stroke is ascertained in the following way:—Taking a 12-inch accumulator having a stroke of 22 feet, and working at a pressure of 750 lbs. per square inch:—

$$\text{Area of 12-inch ram} = 113{\cdot}097 \text{ square inches.}$$

$$\text{Energy stored} = 113{\cdot}097 \times 750 \times 22 = 1{,}866{,}150 \text{ foot-lbs.}$$

$$\frac{1{,}866{,}150}{33{,}000} = 56{\cdot}5 \text{ horse-power acting for one minute.}$$

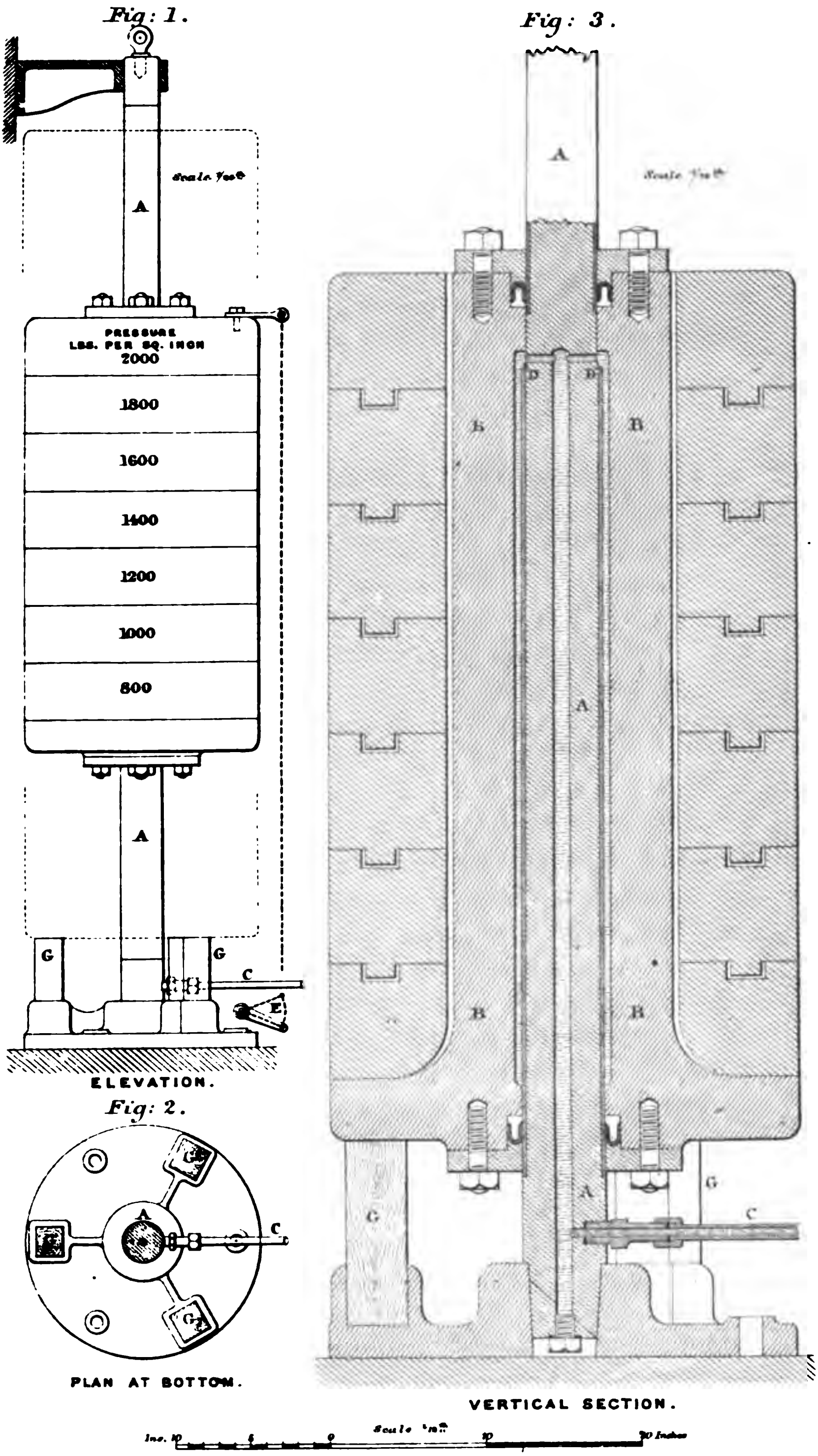
This store of power is capable of being given out as required, either quickly or slowly, according to the working of the appliances.

Mr. Andrew Betts Brown has devised an accumulator by applying steam to one side of a piston which acts upon a water ram. This is shown by Plate 6, which is taken from the *Proceedings of the Institution of Mechanical Engineers.* This accumulator consists of a large steam cylinder 36 inches in diameter, fitted with a piston C, and a piston rod D, which forms the ram of a hydraulic cylinder E, having $\frac{1}{15}$th the area of the steam cylinder B. A steam pressure of 50 lbs. per square inch, therefore, gives a water pressure of 750 lbs. per square inch in the hydraulic cylinder (less the amount of friction). Steam is admitted to the top of the accumulator cylinder (at F) from the ordinary donkey boiler, or the main boilers. The pumping-engines AA are supplied by a branch,

G, from the opposite side of the cylinder, and deliver the water from their pumps into the hydraulic cylinder at H. The bottom of the accumulator-cylinder B is open constantly to the exhaust K. When steam is turned on to the accumulator, the engines start, at the same time pumping up the hydraulic ram D, and they continue working until the steam-piston rises high enough to close the steam-pipe orifice G. The engines then stop, but when water is drawn from the accumulator by the action of the hydraulic machinery, the steam-piston descends, maintaining the pressure of 750 lbs. per square inch upon the water; at the same time by opening the steam-pipe G, it starts the engine again, by which the accumulator is replenished.

An accumulator has been designed by Mr. Tweddell to meet the variation of demand for high-pressure water, such as arises when only one appliance is at work in a system of hydraulic pipes supplying numerous shop tools. This is shown by Plate 7, from the *Proceedings of the Institution of Mechanical Engineers.* The ram or spindle A of this accumulator is fixed, and acts as a guide, whilst the cylinder B slides upon it, and is loaded with the weight necessary for giving the required pressure to the water. The water is pumped in at the bottom at C, and fills up the annular space surrounding the spindle. The whole weight has to be lifted by the water acting only on the shoulder D, which is made by a brass bush ½ inch thick all round the spindle. A compact arrangement is thus gained, and any required cubic capacity is obtainable by lengthening the stroke. The accumulator is supplied by two pumps, each 1⅝ inch diameter and 3½ inches stroke, running at about 100 to 120 revolutions per minute. When the loaded cylinder B reaches the top of its stroke, it is made to close the suction cock E of the pumps, thus stopping the supply of water. When it is desired to put in a new packing-leather at the bottom, the weighted cylinder is let down to rest upon blocks placed on the wood chocks G at the bottom, and the spindle is drawn up out of its tapered seat by the eye-bolt at the top. To

ACCUMULATOR.



renew the top leather, the bracket holding the top end of the spindle has to be removed. This accumulator (having only a small area) falls quickly when the water is withdrawn, thus producing a combined blow and squeeze, which is of great advantage in hydraulic rivetting.

A means of intensifying pressure is shown by Fig. 22 (from the *Proceedings of the Institution of Mechanical Engineers*). A pipe A conveys low-pressure water into the cylinder B. The pressure on the piston C acts upon the smaller ram D, and gives an increased pressure to the water in the second cylinder E, in proportion to the relative areas of the piston C and the ram D. In the illustration the piston is 19 inches, and the ram 3¾ inches, in diameter. A pressure of 60 lbs. per square inch on the piston gives 1540 lbs. per square inch on the ram. The water from the pumps enters through the inlet G, and passes out at H to the machine to be worked by it. No water is consumed from the low-pressure cylinder, but it is simply driven back by the force pumps into the low-pressure accumulator or mains.

The loss of useful effect between the pumps and a properly packed accumulator is but trifling. Experiments carefully made by Mr. Tweddell are recorded of the working of two pumps delivering water into an accumulator. The exact height that the ram was raised by the strokes of the pump was registered. With one pump working, 1694 cubic inches was the theoretical delivery of the pump for 20 strokes, and 1614 cubic inches was the actual quantity pumped into the accumulator, showing a loss of only 4¾ per cent. With both pumps working, the corresponding quantities (for 20 strokes) were 3388 cubic inches, and 3278 cubic inches, showing a loss of only 3¼ per cent. It was noticed in these experiments that 1250 lbs. per square inch was the ascending pressure in the accumulator, and 1225 lbs. per square inch was the descending pressure. In ascending, the friction had to be overcome by the pump in addition to lifting the load, and in descending, the friction had to be overcome by the load itself; the amount of

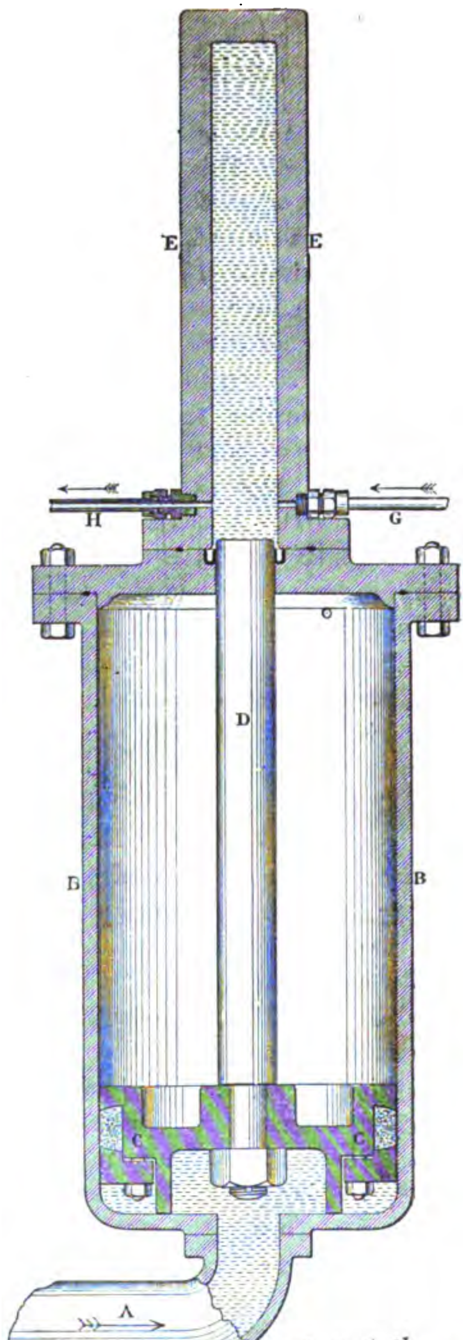


Fig. 22.—Intensifying Accumulator.

the friction will, therefore, be half the difference of pressure in the two cases, or 12½ lbs. per square inch, which is equivalent to 1 per cent. of the power.

Messrs. Clark & Standfield have arranged a differential accumulator for working hydraulic lifting-presses. In their accumulator the dead-weight of the machinery, which has to be raised and lowered, is constantly balanced, so that only a small additional power is required to give it motion. Three accumulator-rams, or plungers, are usually employed, two of which are of such dimensions as to produce a pressure on the ram of the hydraulic press exactly sufficient to balance the dead-weight of the machinery carried by it. In this condition the accumulator and the hydraulic press are in equilibrium, and a very small increase or decrease of pressure suffices to cause the hydraulic ram to ascend or descend, as the case may be. An extra load is then put on the accumulator sufficient to cause it to descend, and to raise the hydraulic ram with any desired load upon it. The third plunger is placed centrally under the head of the accumulator, and the pipes communicate with the two outer plungers so that all three can be connected at will. When the accumulator is down, and the ram is elevated (as just described), then if the communication is opened between the three plungers, the weight of the accumulator, which was at first supported by two plungers, being now supported by three, the pressure on the water is diminished, and consequently the accumulator ascends and descends. In order to raise it again it is only necessary to allow the water to escape from the central ram, when the whole weight becomes supported on the two plungers as before, and the pressure is consequently increased and the ram again ascends. A small pump is employed to keep the accumulator charged.

In order still further to diminish the loss of power entailed by hydraulic rams when raising and lowering heavy weights, Messrs. Clark & Standfield compensate for the varying immersion of the ram. When a ram is raised in the ordinary

manner it is evident that, as it ascends out of the water into the air, it increases in weight, and its balancing power diminishes by an amount which is equal to the weight of a column of water of its own bulk. Similarly, as the plunger of an accumulator descends, it loses a weight equal to the bulk of a column of water which it displaces, and both of these actions concur to diminish the power of the machine more and more as it approaches the full extent of its stroke. To obviate this, the load on the accumulator is increased, as its plunger descends, by a weight of water sufficient to compensate for the varying immersion of the plunger and of the ram of the press. By this means the dead-weight of the machine itself is counterpoised in every position, and the only power required to work the machine is that which is requisite to raise the load itself and to overcome friction. By the same means increased power is given at the end of the stroke, by adding to the load a greater weight of water than is required for compensating for the varying immersion of the rams and plungers. Conversely, decreased power may be given at the end of the stroke by causing weighted tanks or vessels (which form the load of the accumulator) to descend into water.

Where it is desirable that two or more rams should ascend synchronously through equal distances (as, for instance, in the two ends of a bridge or canal lift, or in raising guns) two or more plungers are combined into a group beneath one accumulator, so that as the plungers descend, all the rams ascend through uniform distances. In order to cause all four corners of a bridge or other moving apparatus (which is supported by presses at its two ends) to ascend or descend in a horizontal position, means are provided for allowing an escape of water from beneath either of the rams, if from any cause one of them should become elevated above the other.

Many years ago, Lord Armstrong arranged for the Tyne Commissioners, an air accumulator to work at about 250 lbs. to the square inch. He had some hydraulic cranes put on board a screw hopper barge, used for discharging ballast

from vessels lying in the pool of the river, and taking it for deposition out to sea. These cranes lifted 2 tons, and were able to discharge 60 tons an hour. They had hydraulic lifting, turning, and traversing motion applied to them. As it was not considered practicable to introduce an accumulator on this small barge, a cast-iron air vessel was adopted to work at 1000 lbs. on the square inch. Some difficulty was experienced in the first instance in working the air pump with this high pressure, but by introducing a small stream of water with the air on the suction side, and by allowing the water to fill up the spaces between the ram and the valve, not only was all difficulty overcome, but even a higher air pressure was able to be used. Before this small stream of water was employed, a certain amount of air remained in the cylinder, and as this air was not forced out by the plunger, it prevented the full amount of air at the end of the stroke from being sucked into the cylinder for the next stroke. The introduction of a small quantity of water caused this space to be taken up by the water, and so that difficulty was overcome. Owing to the air getting mixed with the water, a cream was formed, which was obviated by the application of water in the small air-pump. These cranes are still at work.

On board one of the P. and O. steamers (the "Massilia") hydraulic machinery is now employed in which air vessels are introduced, working at a pressure of 1000 to 1200 lbs. on the square inch. These air vessels are composed of wrought-iron pipes 8 inches in diameter.

At the outset of the employment of water-power, it was feared that the water in the pipes and machinery might freeze. This, however, has been found not to be a difficulty where well-known precautions are taken. The working parts should, where possible, be placed under ground, or should be cased in, if they are above ground. In frosty weather the water should be run out of all valves and cylinders which cannot be cased in, and protected, as soon as the working of

the machine ceases. A very small gas jet or lamp placed near the unprotected parts will prevent freezing.

Experiments have also shown that a mixture of glycerine and water prevents the effects of frost to a temperature as low as 16° Fahr., provided the glycerine has a specific gravity of 1·125, and that it is mixed in the proportion of one part of glycerine by weight to four parts of water. Where water is scarce and is used over again in the machines (by returning the exhaust water from the machines to a reservoir), such addition of glycerine is more easily resorted to. Where only moderate risks of frost have to be dealt with, the proportion of 1 gallon of glycerine to 300 gallons of water proves effectual. If the water is at a high pressure, such as 1500 lbs. to the square inch, it is less liable to freeze than when it is at a low pressure.

THE FLOW OF SOLIDS.

Hydraulic forging presses have revolutionised the treatment of large masses of iron and steel, by enabling immense pressures to be brought to bear on the molten metal, and by means of fluid compression ingots are produced of a soundness which was hitherto impossible of accomplishment.

The employment, in recent years, of iron in increasingly large masses has involved the consideration of how the continuity of the fibre can be maintained, and what the conditions are which have to be observed in order to prevent break of continuity, or a diminution of the calculated strength of the mass. The investigations of the late M. Tresca (recorded in the *Proceedings of the Institution of Mechanical Engineers*, 1867 and 1878) have thrown much light on the subject, and are of practical value in regard to forging, under a pressure or squeeze, instead of by a blow. M. Tresca applied the expression, "the flow of solids," to his investigations, and the singular facts which he established indicated that an entirely

new branch of observation had been opened out, to which M. de Saint Venant gave the name of "plastico-dynamics." Fig. 23 shows the result of applying pressure to discs of lead. Ten discs of lead (each 0·12 of an inch thick, and 3·94 inches diameter) were subjected to pressure, by which the lead was forced to flow through a concentric circular orifice 1·18 inch

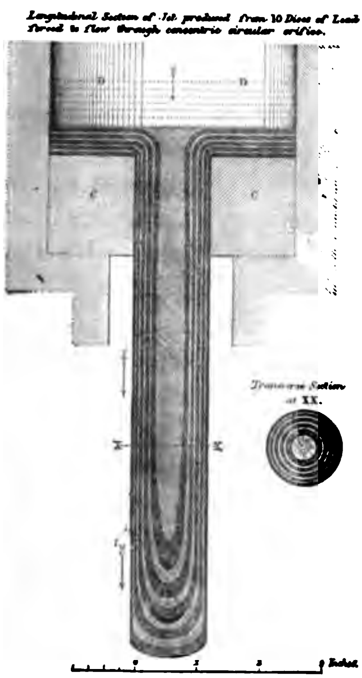
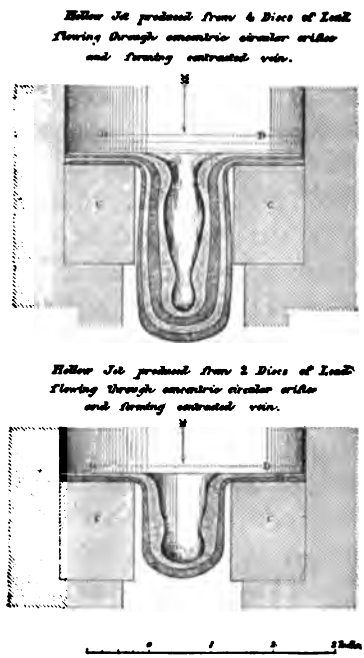


Fig. 23.



Figs. 24 and 25.

diameter in the movable disc CC placed at the bottom of a cylinder, a plunger in which exerts the pressure.

The dotted lines in the cylinder show the original positions of the discs, the upper surface being at DD. On applying pressure the jet reached 7·87 inches, which is the position in the figure. An examination of the jet proved that the layers remained flat back from the central jet, and that they bent over from this area so as to flow into the jet simultaneously, the external surface being formed of the bottom disc, which

has assumed the shape of a cylindrical covering. The other layers form separate tubes concentric with the jet, all being closed at the outer end by a cap formed of the central part of the disc.

A further experiment with a cylindrical block having a smaller height, compared with the diameter of the orifice, gave a result as shown on Figs. 24 and 25.

The orifice in these two cases was 1·58 inch diameter, and each disc was 0·12 of an inch thick. DD (as before) was the original position of the layers. It is interesting to notice that the diameter of the jet is not that of the full diameter of the orifice, but a "vena contracta" has been found, such as occurs in the flow of liquids. In further experiments the undulations which were observed in the metal corresponded with the relative motions of the particles of a similar vein of fluid.

Many other metals besides lead were subjected to pressure through an orifice, and the general conclusion arrived at from them was, that the particles of solid bodies flow under pressure similarly to liquids. Any alteration in the shape of the orifice, from the circular to the polygonal, or eccentric, produced torsional movements of the metal corresponding to the gyratory movements which occur in the flow of a liquid through an orifice, which is not placed symmetrically to the sides of the vessel containing it. When the metal was pressed through more than one orifice in the die, it was observed that the jets nearest the centre were rather larger than those near to the sides of the cylinder, the lesser effect being due to the friction of the sides. This difference in pressure on different parts of a solid mass explains the displacements that take place in the interior of the mass.

The experiments established that the pressures exerted on the surface of a solid body are transmitted throughout the whole interior of its mass, and tend to produce in it a flow which is propagated from particle to particle, and which necessarily develops itself in the direction where the resistances to the flow are the least; also that the pressures thus

transmitted determine in a fixed order the changes of form at each point. Further, these changes of form are attended by a loss of pressure between one point and another, similar to, but even greater than, that in the case of the flow of liquids.

In the processes of rolling and forging iron, the observations of M. Tresca have a practical value, as indicating the necessity for the application of a pressure or blow sufficiently powerful to reach the interior of the mass in order to enable the metal to flow, and its fibrous continuity to be preserved.

HYDRAULIC PRESSES AND LIFTS.

The Bramah Press is a practical application of the law of the equal transmissibility of fluid pressure, by which a force that is exerted by a small ram on one unit of water-surface is capable of being exerted over any number of units of water-surface in direct communication with the cylinder which contains the water that receives the initial pressure.

In presses of small diameter the calculation of the thickness, and the proportioning of the metal round the orifice admitting the water, have been matters of no difficulty, but the gradual increase in the size of presses to meet the development of the use of hydraulic power has involved new arrangements of construction.

In determining the thickness of hydraulic cylinders, where the thickness of metal is not small as compared to the radius, the conditions of strain on the inner and outer radius of the metal are not the same, so that it must not be assumed that the thickness can be increased in direct proportion to the strain.

For thin cast-iron cylinders and water pipes—

P = pressure in lbs. per square inch.

R = internal radius in inches.

T = thickness in metal.

C = coefficient for cohesive strength of the metal.

Then

$$\frac{T}{R} = \frac{P}{C}$$

When C = 16,500 lbs. for the bursting tension.
= 5,500 lbs. for the proof tension.
= 2,750 lbs. for the working tension.

The cylinders of presses that are subject to great strain are now best made of steel that has been subject to fluid compression, on Sir Joseph Whitworth's plan, by which a more uniform molecular structure, strength, and ductility, is preserved throughout the whole body of metal than can be obtained otherwise. The usual thicknesses are for a 14-inch press, $2\frac{3}{4}$ inches, with a maximum tensile strain of 9 tons on the inner surface when worked at a pressure of $2\frac{3}{4}$ tons to the square inch. An 18-inch press would have a thickness of $3\frac{1}{4}$ inches, the usual working pressure not being more than $2\frac{1}{2}$ tons per square inch. The tensile strain on the inner surface of the press is determined by the formula deduced by Hooke.

$$P = p \cdot \frac{R^2 + r^2}{R^2 - r^2}$$

where P = the tensile strain per square inch on the inner layer,

p = pressure per square inch on the cylinder internally.
R = the outer radius.
r = the inner radius.

Experiments that were made to determine the method of constructing the presses for canal lifts are described elsewhere on pp. 47 to 53.

In 1864, Sir J. Whitworth erected a hydraulic press to forge and to press fluid steel, and the result showed such advantages over hammer forging, that another was erected in 1870, with a 24-inch cylinder working at a pressure of 2 tons to the square inch. Two others having 30- and 34-inch cylinders followed, with a pressure of 3 tons to the square inch, although the working pressure rarely exceeded 2 tons to

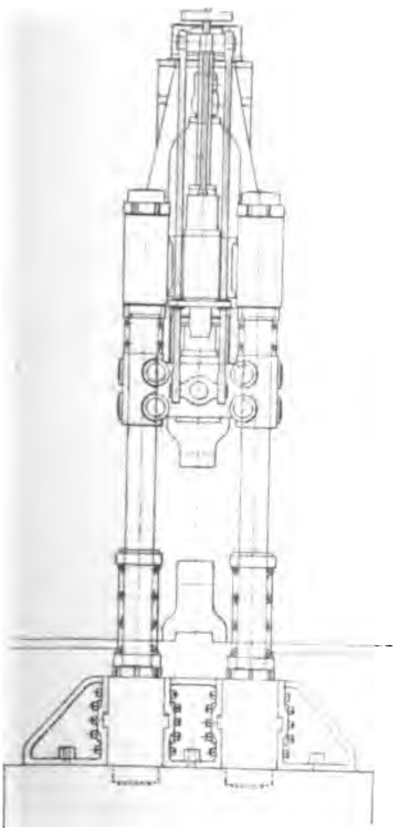
the square inch. The forging presses are all worked by single cylinders in the press heads. In that for pressing fluid steel there are three cylinders below the base plate, which is raised by them. On it is a mould containing fluid steel which is pressed against a fixed plunger in the press head. By the application of intense pressure to fluid metal in a mould, its whole length can be diminished one-eighth in less than five minutes, the air cells being expelled. The two screw propeller shafts of H.M.S. "Inflexible" were made from pressed metal a few years ago at the Whitworth works. They were 283 feet in length, 17 inches in diameter, with a 9-inch hole through them. They weighed 63 tons, compared with 97 tons, which it was estimated would have been the weight of wrought-iron shafts. The strength of the compressed metal shafts was 40 tons to the square inch, and the ductility was 30 per cent. The pressure applied was 8000 tons, and it was found necessary to employ a pressure of from 6 to 9 tons per square inch as soon as the metal was run into the mould, as the gases could not be expelled when the metal was in a semi-fluid state.

The employment of hydraulic pressure for the manufacture of steel guns was referred to by Major Mackinlay, R.A., in a paper which he read at the Royal United Service Institution in 1885. The construction of a steel gun by the aid of hydraulic presses engaged Sir Joseph Whitworth's attention, and he applied to this purpose the principle which he had successfully used to manufacture hollow propeller shafts. In this case the solid cylindrical ingot from which the shaft is to be made is first bored and converted into a hollow cylinder. It is then heated, and a hollow steel mandrel of smaller diameter than the interior is placed inside it, and the action of hydraulic pressure is brought to bear upon the external longitudinal surface of the cylinder. The press squeezes the metal against the mandrel within (which is kept cool by water flowing through it), the cylinder being turned over during the operation, so that it is evenly pressed throughout. The effect of this pressing is to bring the internal diameter of the

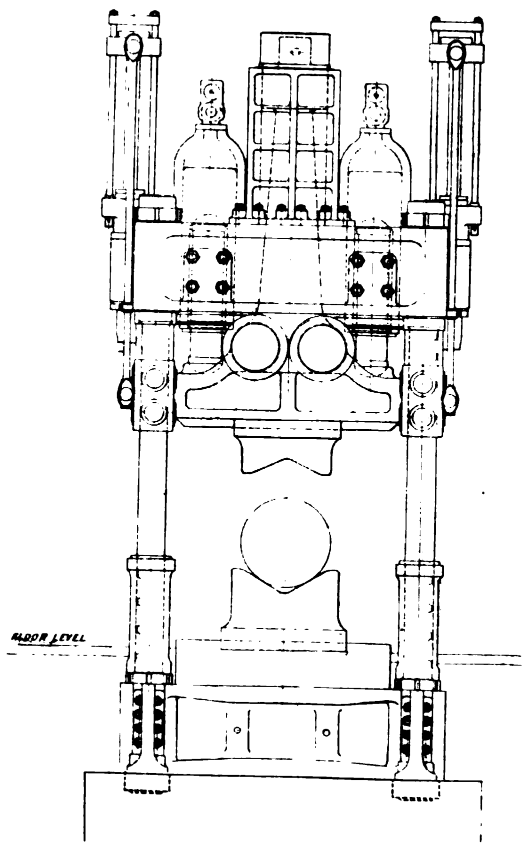
cylinder to that of the mandrel, and at the same time the length of the cylinder is increased. By reheating the cylinder, and repeating the process of pressing with smaller mandrels, the final proportions of the propeller shaft are obtained. A similar process is employed in making steel guns and presses. The ingot is cut into thick rings which are squeezed in presses round mandrels, as already described.

Since the successful application of the forging press by Sir J. Whitworth, the demand for large forgings of every description has compelled its adoption by firms who desired to acquire, or to maintain, a position in the front rank of makers of the heavier class of steel forgings. The size of forgings has progressively increased, and to deal with them efficiently, larger and larger presses have been, and are being, constructed. The most recent are capable of turning out any variety of forgings, besides plain round shafts, and at a minimum of cost in labour.

Up to a certain size the single-cylinder system of construction is allowable, but in the more powerful presses it becomes necessary to substitute double cylinders. The latter system enables the weight and magnitude of the individual parts to be brought within practicable limits, besides which the width of the entablature is reduced to a minimum. The reduction of width is an advantage, inasmuch as it allows the sling chains of the crane to approach so much nearer to the anvil, thus giving greater command over the ingot without having to use excessively heavy balance weights on the porter bar. The 5,000-ton press, illustrated on Piate 8, constructed on the double-cylinder system, patented by Mr. Charles Davy, and built by Messrs. Davy Brothers, Limited, Sheffield, has been in use at Messrs. Charles Cammell & Co.'s Ordnance Works since 1886. On referring to the Plate it will be seen that, by placing the cylinders near to the columns, the bending movement of the entablature girders is very moderate compared with that of a press having a single cylinder of equal power placed centrally. The difference in favour of the former is as



END ELEVATION.



SIDE ELEVATION.

West, Newman Photo.

38 : 100, and it is obvious that the single-cylinder construction would require much heavier girders. In effect the bending stress is divided between the entablature girders and the crosshead or tool holder, so that while each of the parts in question is not excessively heavy, the total weight of the press remains about the same.

To ensure the parallelism of the crosshead, a shank is attached to it extending upwards into a slide bar fixed centrally over the entablature. The ends are also fitted with guide blocks encircling the columns, the whole forming an inverted T piece, guided at the top of the shank and at the ends of the horizontal member. The pressure of the rams is transmitted to the crosshead through long spherical ended rods, seated on the crosshead and near the tops of the rams, which are made hollow for this purpose. The side strains, which inevitably arise when the press is in action, are thus taken on efficient guiding surfaces, leaving the rams free from all side stress. With this arrangement of guides, it follows that forgings can be pressed at a distance from the centre of the anvil; and forgings can be made, which would be impossible were the side stress taken on the ram, as obtains in single-cylinder presses.

A low-pressure service of water, of about 50 lbs. per inch, is connected to the main-pressure cylinders, and fills them as the press descends upon the forging, when the high-pressure pumps start and automatically cut off the low-pressure. The velocity of descent, when taking up the clearance between the top tool and the forging, is about 2 ft. per second, and the pumps are calculated to depress the crosshead under high pressure half an inch per revolution. The pressure generated is always measured automatically by the resistance of the forging, and power is thus economised to the greatest extent. The engines have a pair of 34-inch cylinders, 4-ft. stroke, coupled direct by side cranks to a three-throw shaft from which the pumps are worked. These are single-acting rams, 6-inch diameter and 12-inch stroke, working at pressures vary-

ing from 0 up to $2\frac{1}{4}$ tons per square inch maximum. The observed speed of the engines exceeds 100 revolutions per minute.

The main-pressure rams are 36 inches diameter, the lifting ram 9 inches, and the stroke 7 feet. The relative areas are 16 to 1, and as the high-pressure pumps are used for lifting, as well as pressing, the rate of lifting is proportionate.

Advantage is taken of the high speed of the press in its downward and upward strokes to adjust the crosshead to varying thicknesses of the forgings. This simplifies the construction immensely, and dispenses with a number of hydraulic cylinders required in forging presses, where the entablature is moved for the vertical adjustment. It is worth noting that there are only four leathers in this press, whereas a press with a moving crosshead may have as many as fifteen, besides those required for sliding pipe connections.

CYCLONE HYDRAULIC BALING PRESS.

The packing of textile or fibrous material so as to minimise the risk of fire on ship board has received much attention at the hands of those engaged in the construction of presses, and one form, which is the invention of Mr. James Watson, and is manufactured by Messrs. Fawcett, Preston & Co., of Liverpool, deserves notice. The special feature of this press (which is called the "Cyclone") consists in combining fixed or revolving filling boxes with revolvers having several chambers by which several bales are being pressed simultaneously. Illustrations of this form of press are given on Plate 9. Fig. 1 shows a press with a two-chamber revolver, and Fig. 2 shows one with three chambers. The following description will explain the method of working:—

The press is fitted with two upper rams of large diameter and very short stroke, and two lower rams of small diameter and very long stroke. One rigid revolver, having three

PLATE 9.

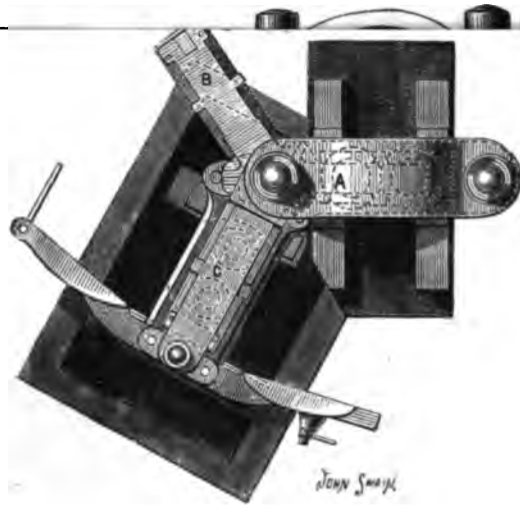


Fig. 1.

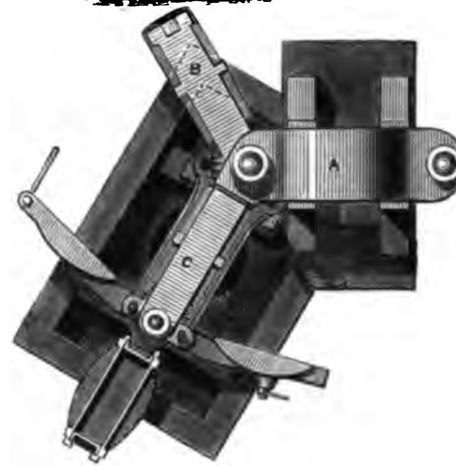


Fig. 2.

CYCLONE HYDRAULIC BALING PRESS.

chambers, is fitted on one of the main columns, and revolves thereon from the position over the long stroke or bottom rams to that over the short stroke or top rams; one fixed deep box is fitted in position over the bottom rams. The fact that this revolver admits simultaneously of one bale being in one chamber cver the large rams, of a second bale being in a second chamber over the small rams, and of a third bale being in the third chamber out of the press and in the lashing position, enables very large out-turns to be made. The working of the press is as follows:—A bale is first pressed up into the A chamber of the revolver. It is then turned a third of a revolution, placing the A chamber with its bale in waiting position, where the preliminary lashing is done. The chamber B is then over the lower rams, and a full box having turned into position over them, a bale is compressed into the B chamber of the revolver, which is again turned the third of a revolution, placing the chamber A with its bale over the upper rams, the B chamber with its bale in the waiting position to receive the preliminary lashing, and the C chamber over the lower rams and another box full of material to be pressed.

The regular action of the press now commences. The inlet valve is opened to the upper rams which fully compress the bale in the A chamber of the revolver. The hoops are made fast in the usual way, and the outlet valve is opened and the rams fall when the bale is turned out of the press. When the pumps finish the pressure on these rams, finally compressing the bale in the chamber A, the inlet valve to the lower rams is opened, allowing the water from the pumps to flow into the lower cylinders, raising these rams, and compressing a bale into the C chamber of the revolver. These lower rams, when near the end of their stroke, withdraw the lock bolt of the main doors by means of a tappet rod which is fixed to the follower. This tappet rod also stops the rise of these rams at any desired position, by lifting the weighted lever of a relief valve at the bottom of the press. The doors are then pushed back. All three chambers of the revolver

are now ready to be moved round a third of a revolution, which brings the A chamber in position over the lower rams, the B chamber with its bale three-fourths hooped, over the upper rams, and the chamber C in position to receive the preliminary lashing, where it gets its bale three-fourths hooped. The loose plate in the A revolver is then allowed to fall on the follower of the lower rams, which is waiting for it at top of the box. The outlet valve of the lower rams is opened, and those rams fall with this loose plate to the bottom of the box, the stop is withdrawn, and the boxes turn half a revolution, placing a box full of cotton over the lower rams and under the A chamber of the revolver. As soon as the B chamber of the revolver strikes the stop, fixing it in position over the upper rams, the inlet valve to those rams is opened, and the bale in that chamber is fully compressed by the rise of the rams. The inlet valve to the lower rams is then opened, compressing another bale into the A chamber of the revolver; these rams withdraw the lock bolt of the main doors, which are then pushed back. All three chambers are thus again ready to be pushed round. The bale in the chamber B having been hooped and turned out, leaving that end ready to move into position over the lower rams, the bale in the chamber C has received the preliminary hooping, and is ready to move into position over the upper rams, and the A chamber is ready to move with its bale to the position for hooping, and so on.

It will be seen that three bales are under treatment simultaneously, and that the pumps are practically continuously at work pumping into either the lower or the upper cylinders. Thus, at the same moment, a first bale in No. 1 chamber of the revolver is receiving the final pressure from the upper rams; a second bale which has been previously pressed up by the lower rams into No. 2 chamber of the revolver, and moved out from its position above the lower rams is receiving its preliminary lashing; and material for a third bale is being filled into the deep box through the frame of the revolver chamber, ready to receive the preliminary

pressing from the lower rams, so soon as the water under pressure supplied by the pumps is diverted from the upper rams to the lower rams. The speed of the pumps is about 100 feet per minute.

The materials pressed can be reduced to a great density. The result of a series of observations on bales of American cotton gave from 16·1 to 22·5 lbs. per cubic foot as their density after treatment in a Cyclone press. The shape and dimensions of the bale are retained by this method of pressing, whereas previously, the material, although subject to enormous pressure, rebounded on the pressure being withdrawn. No case of fire from these hard pressed bales is said to have occurred.

ANDERTON HYDRAULIC LIFT.

Mr. Leader Williams adopted hydraulic power for lifting barges to connect the river Weaver with the Trent and Mersey Canal, at Anderton. The difference of level being 50 feet, the process of locking had previously been tedious and expensive. The plan that was adopted consisted in constructing a wrought-iron aqueduct by which the canal was brought to a point where the barges could be best raised and lowered to and from the river. Mr. Duer (who was resident engineer of this work) described it fully in a paper read before the Institution of Civil Engineers in 1876.

The wrought-iron aqueduct is 162 feet 6 inches long by 34 feet 4 inches wide, in three spans of 30 feet, 75 feet, and 57 feet 6 inches. It is divided into two channels by a central web, the depth of it and of the sides being 8 feet 6 inches. The water is 5 feet 3 inches deep, and with the aqueduct gives a total weight of 1050 tons. This weight is partly supported by columns which rest on cast-iron cylinders containing concrete. These are carried on masonry foundations built on piles. A water-tight connection is obtained by bolting the

wrought-iron bottom-skin of the aqueduct upon a cast-iron bed-plate that is built into the masonry with a layer of red lead between. The outer edges are caulked with wooden wedges, and the sides are run with Portland cement. Each end of the aqueduct is fitted with wrought-iron lifting-gates, made water-tight by indiarubber strips fitted between them and the aqueduct. Each gate weighs 27 cwt., and is counter-balanced by weights. The lifting of a gate can be effected in a minute and a half by a crab. The gate is raised 7 feet 6 inches clear of the water, which enables the highest barge to pass under. The lift is double, so that by means of two troughs, with their floating barge load, the upper one, in descending, can be adjusted by the admission of water, so as to raise the lower one. These troughs are each 75 feet long by 15 feet 6 inches wide. The lighter barges hold 30 tons, and the heavier 100 tons of goods. The troughs have lifting-gates at their ends like those on the aqueduct. One central vertical ram, 3 feet in diameter, supports each trough, whose weight (with the water and barge) is 240 tons, which is equivalent to a pressure of 4¾ cwt. per square inch of the ram. The rams are raised by presses controlled by an equilibrium valve for opening and closing communication between them. A 5-inch pipe connects these presses, and a 4-inch pipe conveys the water from the accumulator to the presses. One man in a valve house at the top of the aqueduct works the lift by means of shafting and gearing. When a trough descends into the pit, it is immersed fully 5 feet. The depth of water while the trough is being lifted, however, must not be more than 4 feet 6 inches, the extra water being drawn off by syphons which dip into the water while a trough is descending. The air within the syphon is driven out into the trough by its shorter leg, which nearly fills the trough with water. When it is again lifted, the syphon draws water (owing to the partial vacuum within it) out of the inside of the trough, and thus acts automatically. Each trough can, if necessary, be lifted separately by the engine and accumulator, but this occupies half

an hour, whilst the double lift is made in from two to three minutes with a 10 HP engine. A single lift could only take two barges up, or bring two down in eight minutes, with an engine of six times the power required for a double lift.

The abstraction of 15 tons of water from the canal (representing a layer of 6 inches over the bottom of the trough) provides the chief means required for raising a barge. The remainder of the power (about one-twelfth) is obtained from a small steam-engine and accumulator. The double-lift arrangement enables expedition and economy to be secured, as each press alternately utilises the weight of the trough, which rests upon it, to raise the other trough from the low to the high level.

A saving of water also is effected as compared with locking, inasmuch as only 15 tons are used at each operation of raising a barge, whereas with a fall of 51 feet through a chain of six locks, a much larger quantity would be wasted. Under the most unfavourable circumstances (for instance, when two similar barges have to pass each other through locks with this fall) the column of water taken from the upper level would be equivalent to the area of one lock multiplied by the total fall. If, however, a series of barges were arranged to follow each other in the same direction, less waste would ensue. If six barges were to ascend with all the locks empty, the first would take five lockfuls, and the other five would take one lockful each from the upper level, making ten lockfuls for the ascending barges. A similar number of descending barges would take eleven lockfuls of water, making twenty-one altogether, or 175 feet, whereas the lifts would require six layers of water each 6 inches deep, or 3 feet, which is only 1·7 per cent. of that which would be used for locking. This lift is capable of taking eight barges up and eight down in an hour. Assuming eight to be laden with the average load of 25 tons each, the lift can thus transfer 12,000 tons per week, at a cost of 2·16 pence per ton. The parliamentary tolls were as follows:—Per ton for all goods, 1d; for each laden barge, 1s; for each empty barge, 2s. 6d.

In 1882, one of the hydraulic cylinders of the Anderton lift was fractured during its use. At the time of the accident one of the troughs had been raised to the top, and the aqueduct gate was partly open, when the trough fell, owing to a side of the press having blown out. This occurred before the six inches of water had been admitted to it, so that it was empty, and the pressure on the cylinder of the press was calculated to be 532 lbs. per square inch. On applying a pressure of 800 lbs. to the second press, it cracked through the hole for the inlet pipe. The fractures in both presses were similar in position and character. The part that failed in the first press was not the press proper, but the upper casting, or press head, with the opening for the 5-inch supply pipe. The continuity of the circumference was practically destroyed at that part, a greater strain being imposed thereby on the surrounding metal, and, in addition, the thickening of the cylinder at the inlet caused unequal contraction on cooling, and consequently rendered the casting less sound. From an investigation that was made by Mr. Edwin Clark it appears that the following were the conditions at the time of the accident:—The water-pressure, as before stated, was 532 lbs. per square inch. The diameter of the ram was 37·5 inches, and the thickness was 2·5 inches. Then by the expression—

$$S = \frac{P.D}{2T}$$

(where S is the tensile strain per square inch of section of metal, P is the pressure per square inch, D is the diameter, T is the thickness), it will be seen that S is 1·78 tons per square inch. In the case of the second press that was tested to bursting, P = 800 lbs. per square inch. Hence S = 2·68 tons per square inch, which is below the strain to which cast iron is usually subjected. If the press had been a simple cylinder, it should have borne—

$$\frac{2 \times 2{\cdot}5 \times 7 \times 2240}{36} = 2090 \text{ lbs. per square inch,}$$

as compared with 800 lbs., which was the actual pressure when it burst.

The failure of the Anderton press caused inquiry to be made into the circumstances of the case, as similar lifts were being proposed for other places, notably in France, on the Neuffossé Canal at Les Fontinettes, near St. Omer, and in Belgium, at La Louvière on the Canal du Centre, near Mons.

The observations that have been made to determine the construction of the presses for the Louvière Canal lifts are interesting and important. It was originally intended that the press should be of cast iron, 6 feet 8 inches in internal diameter, with metal 4·72 inches thick. The pressure in the cylinder being 28 atmospheres (about 420 lbs. per square inch), the extreme tension would have been 1·65 tons per square inch. This was considered a safe load for the Belgian cast iron, which bears a tensile strain of 11·43 tons per square inch. The Terre Noire Steel Company of St. Etienne, France, suggested a press of cast steel, constructed in the same manner as an ordinary cast-iron press, but of less metal. Some of these rings were cast and tested. One of them was kept under a pressure of 46 atmospheres for two hours, and proved perfectly water-tight. Trial bars cast at the same time broke at 31·16 tons per square inch, with an elongation of 8·6 per cent. Another ring, chosen hap-hazard was tested. At 50 atmospheres an elongation of ·157 of an inch was measured. On removing the pressure, the press returned to its original dimensions. At 75 atmospheres the elongation was ·197 of an inch, and at 80 atmospheres the press suddenly failed; on examining the fracture a fault 5 inches long, and extending nearly through the whole thickness of the metal, was seen, due to a scale from the mould becoming detached, owing to the high temperature of the casting. Judging from the trial bars, the press should have withstood 240 atmospheres. Owing to this failure it was determined to abandon this form of construction.

Messrs. Cail of Paris next proposed a press of steel plates

bent into a cylindrical form (like a boiler), with rivetted butt joints having internal and external cover-plates. A trial length was built up in rings 6 feet 3 inches high, with covering-rings at the joints. The steel plate was 1·02 inches thick, with a working tension of 7·17 tons per square inch. Although the rolled plate would stand 38 tons, the weakening due to rivetting reduced the margin of safety, and the joints could not be made water-tight. A trial length leaked badly under 30 atmospheres, and at 35 the pumps could not make up the leakage. Ultimately, the press cracked through the cover-plate, and some of the rivets started, at a pressure which could not be definitely ascertained, but was between 48 and 70 atmospheres.

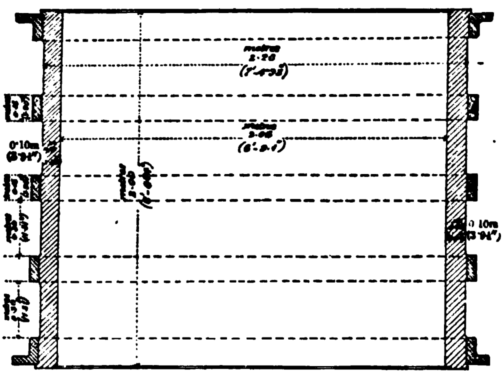


Fig. 26.

While these trials were going on, Messrs. Clark & Standfield had been directing their attention to the placing of steel hoops round the cast-iron presses. The practical difficulty of getting the hoops over the flange of the press presented itself, and it was decided to make the hoops at the joints with flanges like the tire of a wheel. To prevent this flanged tire from being dragged off, a small projection was left on the body of the press, the heated tire was then passed over this, and, in cooling, it fitted tightly behind it. M. Kraft, chief engineer of the Société Cockerill, gave much consideration to the calculations for, and the method of constructing, these presses, and a

trial segment was made by the Société Cockerill, as shown in Fig. 26. This was tried under hydraulic pressure, the expansion being measured by a thin strip of metal put round the cast-iron cylinder, and another strip round one of the steel hoops. The two ends of each strip were connected by means of a spring adjusted by a screw, and were also joined to the short ends of an arrangement like proportional compasses, set to a ratio of 12 to 1. By this means any slight opening of the ends of the strips, caused by the expansion of the cylinders, was shown twelve times its actual size on the long arms of the compasses. Owing to friction (which was, however, reduced to a minimum by lubrication) and other causes, the measurements were not absolutely correct, but the instrument was found to be very sensitive and constant. A satisfactory trial took place in the presence of the ministers, and many Belgian and French engineers interested in the undertaking.

In addition to this trial, M. Génard (on behalf of the Ponts et Chaussées) and Mr. Lyonel Clark (on behalf of Messrs. Clark & Standfield) carried out a series of exhaustive trials on the segment, for the purpose of finding out as nearly as possible the conditions of the several portions of this composite construction under various strains. It is evident that the cast-iron body is subject to a strain at the part covered by the steel coil entirely different from that to which it is subject elsewhere. Very many experiments were made, the pressure being increased gradually, and a measurement being taken at each increment of ten atmospheres. The mean of these, corrected for atmospheric temperature and other causes, was taken, and a normal curve plotted, which gave as the elongation on the cast iron between two coils, and elongations on one of the steel coils, the results shown by Table I. on p. 50.

Were the press a plain cylinder, it would be easy to deduce the tensions from these elongations, supposing the different coefficients of elasticity of the metal under the different tensions to be known; but in either case, before pressure

TABLE I.

Actual Elongations of the Circumference.

	Pressure in Atmospheres.														
	10.	20.	30.	35.	40.	50.	60.	70.	80.	90.	100.	110.	120.	125.	
Elongation between coils,	·208	·573	·960	1·05	1 361	1·805	2 235	2·662	3 07	3·447	3·717	3·966	4·254	4·604	Millimetres.
	·0082	·0226	·0378	·0413	·0535	·0714	·088	·1047	·1209	·1358	·1464	·1635	·1075	·1812	Inch.
Elongation on coils, . . .	·134	·349	·578	·660	·884	1·24	1·618	1·974	2·318	2·696	2·992	3 242	3·475	3·766	Millimetres.
	·0053	·0137	·0228	·0262	·0348	·0488	·0637	·0777	·0913	·1061	·1177	·1315	·1368	·1482	Inch.

was put on the press, the steel coil was already compressing the cast-iron body to some extent. The tensions had, therefore, to be deduced in two ways, by calculation and by graphic means. The sizes to which the coil was bored, and the press turned, were accurately known, and a pressure which would compress the cast iron and elongate the steel coil until they became of equal length was deduced. Although following different methods, both M. Génard and Mr. Clark obtained nearly the same results. M. Génard found the pressure existing between the coil and the press to be 14 atmospheres, whilst Mr. Clark found 13¾ atmospheres. When considering the measured elongations, the tension on the cast-iron body of the press is evidently relieved by this exterior pressure of 14 atmospheres, whereas the tension on the steel coil is increased to the same amount. They, therefore, found that the tensional strains were as shown in Table II. The strains at A are those on the cast-iron press directly under the steel coil, and those at B on the steel coil itself.

It will be noticed that, with the interior pressure of 10 atmospheres, the cast iron is still in compression, owing to the shrinking of the steel coils.

For that portion of the cast-iron part of the press which does not lie directly under the steel coils, it was more difficult to calculate the tensions, for it was nearly impossible to find out to what extent the shrinkage of the steel coil influenced this part. It evidently lay between the maximum (that is, assuming this part to be as much affected by the shrinkage of the coil as the part directly under a coil) and the minimum, assuming the coil to have no influence. Table III. shows the results.

The ordinary working pressure of these presses is 35 atmospheres (517 lbs. per square inch). In this condition, then, the strain on the cast iron under a coil is 1·35 kilogrammes per square millimetre (·857 ton per square inch), for the cast iron between two coils, 3·175 to 3·475 kilogrammes per square millimetre (2·01 to 2·2 tons per square inch), and for the steel

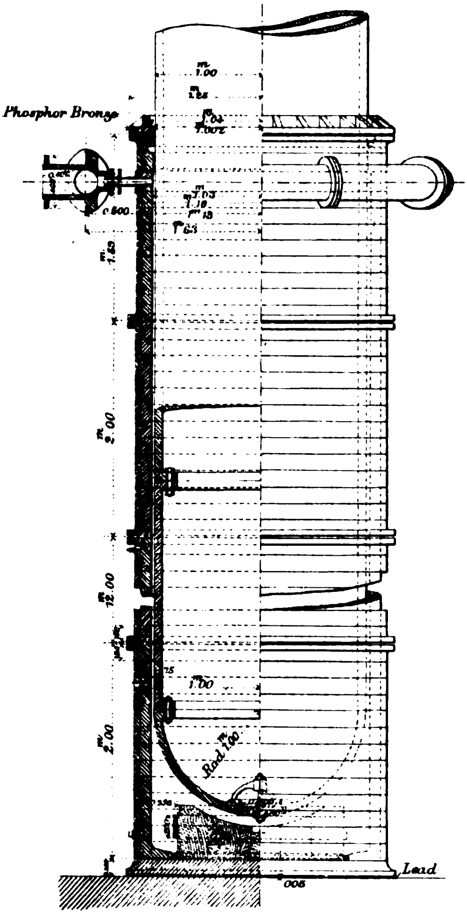
TABLE II.

	Pressure in Atmospheres.												
	10.	20.	30.	35.	40.	50.	60.	70.	80.	90.	100.	110.	
A, . . .	–·6	+·18	·95	1·35	1·72	2·5	3·275	3·95	4·7	5·4	6·05	6·7	Kilogrammes per square millimetre.
	–·381	·1143	·6032	·8572	1·092	1·567	2·076	2·508	2·984	3·429	3·841	4·25	Tons per square inch.
B, . . .	4·33	5·15	6·05	6·4	6·85	7·7	8·6	9·45	10·15	11·29	12·15	13·03	Kilogrammes per square millimetre.
	2·73	3·24	3·84	4·06	4·32	4·89	5·46	6·00	6·57	7·17	7·71	8·25	Tons per square inch.

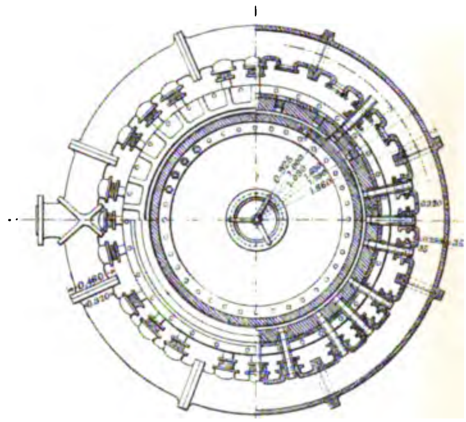
TABLE III.

	Pressure in Atmospheres.												
	10.	20.	30.	35.	40.	50.	60.	70.	80.	90.	100.	110.	
Between	1·05	2·025	3·00	3·475	3·95	4·85	5·75	6·65	7·60	8·50	9·15	10·5	Kilogrammes per square millimetre.
	·667	1·28	1·905	2·2	2·51	3·08	3·65	4·22	4·83	5·397	5·94	6·67	Tons per square inch.
Coils	·57	1·7	2·7	3·175	3·65	4·55	5·43	6·33	7·23	8·1	9·0	9·9	Kilogrammes per square millimetre.
	·362	1·079	1·714	2·01	2·32	2·9	3·45	4·02	4·59	5·13	5·71	6·28	Tons per square inch.

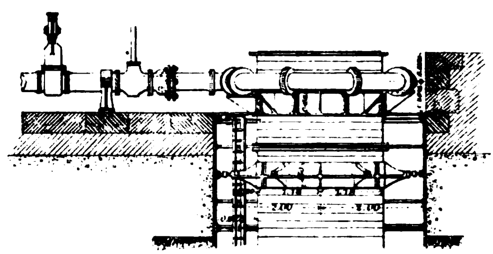
LA LOUVIÈRE PRESS.



½ SECTIONAL ELEVATION. ½ ELEVATION.



PLAN.



Thos Kell & Son, Lith.

coil itself, a tension of 6·4 kilogrammes per square millimetre (4·06 tons per square inch).

The limit of safety fixed by the Belgian Government for cast iron under tension is 2½ kilogrammes per square millimetre (1·59 tons per square inch), and for the steel 7 kilogrammes per square millimetre (4·76 tons per square inch). It is evident, however, that although that portion of the cast iron which falls under the coils, and also for some distance on each side of it, is working under safe conditions, there is a portion which exceeds these limits. It was, therefore, decided by the Government that whilst accepting this form of press, they considered it desirable that a greater number of coils should be shrunk on, and it was eventually decided to make these coils continuous from top to bottom. The disposition is shown on Plate 10.

In this press the shrinkage given to the steel coils is such that with the ordinary working pressure of 35 atmospheres (517 lbs.), no strain whatever falls on the cast iron. This only acts as a water-tight lining, and gives stability as a column, the whole tension being received by the weldless rolled steel hoops. The press is, for convenience of manufacture and erection, constructed in segments, which are afterwards bolted together. The particular coil that terminates each section is constructed with a flange for this purpose. These coils are rolled out of soft Bessemer steel in an ordinary tire-rolling machine. They are 6 inches deep with 5-inch flanges, and in diameter do not exceed that of some express engine wheels. The Société Cockerill succeeded in rolling these in their existing tire mills without any extra preparations. The boring and turning have to be done very accurately, but all the pieces are of one size. The packing of these presses will be hemp and tallow, the same as at Anderton. The gland will be in phosphor bronze. The press itself reposes directly on a carefully levelled stone bed, which rests directly on the concrete at the bottom of the shafts. A sheet of lead ensures water-tightness. The pressure is, therefore, taken directly by the solid

earth, and there is no danger of that common accident, the blowing out of the bottom of the press. The feed inlet (on account of the form of the coils) has had to be considerably modified. It was found impossible to obtain the necessary area of feed-pipe without cutting away some of the coils. Mr. Edwin Clark then devised the ingenious arrangement shown on Fig. 1, Plate 10. A circular supply tube surrounds the press, from which project several smaller pipes, like spokes of a wheel, each one being a feed-pipe. The size of these pipes is 3 inches. The 6-inch coils, therefore, are not much weakened, and these particular ones being made thicker, the press is in reality not weakened at all. The supply has, moreover, the advantage of being remarkably even and regular, owing to the water entering at different points all round the press. The press is stayed against the sides of the well by projecting brackets, furnished with adjusting screws. This is not a very necessary precaution, for the trough itself is so well guided that any deviation from the vertical line is impossible.

In designing these lifts, the principle of the Anderton lift was followed, varied, however, in one important point. It has been stated, when describing the Anderton lift, that the upper trough with its barge is made heavier than the lower one, by the addition of a layer of 6 inches of water, which forces the lighter one up. When the heavier one, however, enters the water at the low level, the displacement of the water diminishes its weight, and requires the action of a differential accumulator to complete the work, by supplying the power necessary to overcome the difference of weight, and to force the rising trough to its proper height. In these lifts this accumulator, with the engines, boilers, pumps, and labour, are dispensed with, by arranging the works so that the descending trough is received in a dry basin from which the low level water is excluded by a gate similar to that applied at the high level. This alteration in the design enables the descending trough to complete the operation of raising the other trough through the full stroke of the ram. Plate 11 gives a general

LA LOUVIÈRE LIFT.

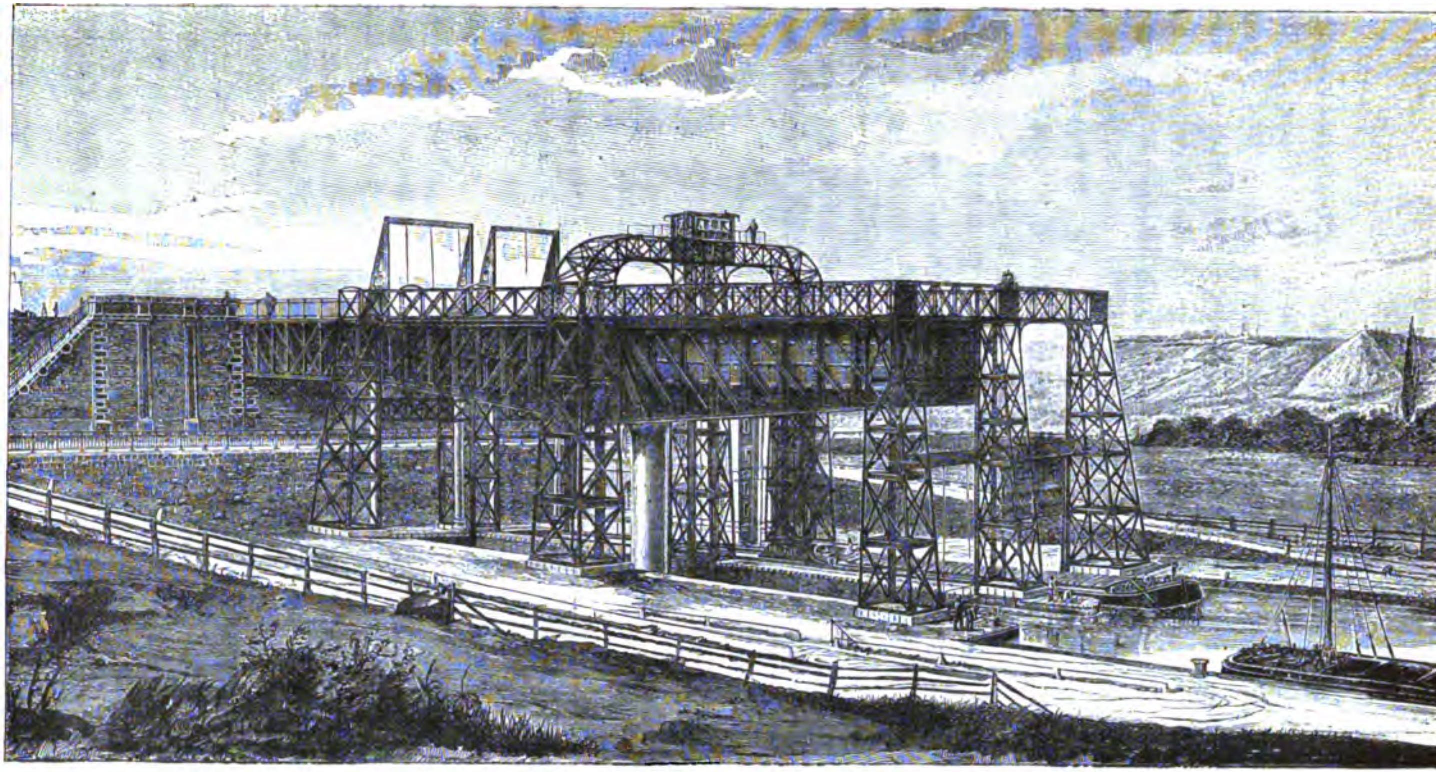


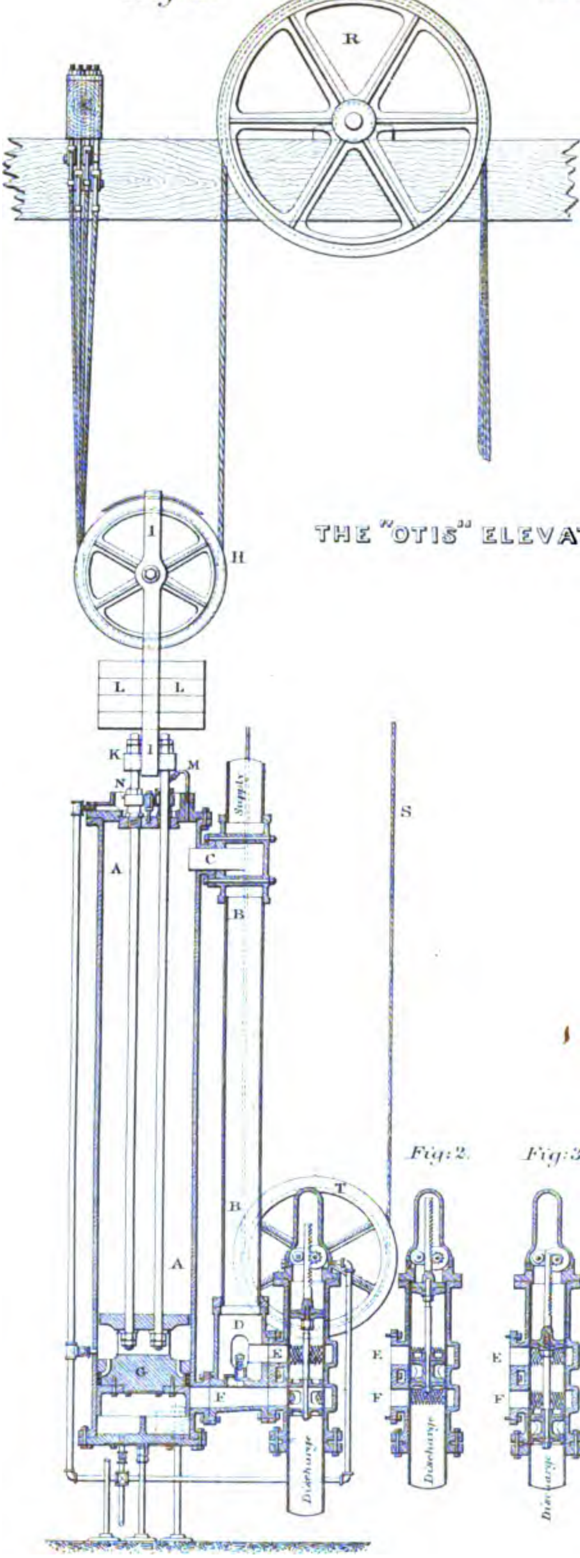
PLATE 11.

view of the hydraulic canal-lift at La Louvière. The Belgian Government is constructing three other lifts to complete the chain of which that at La Louvière was the first. The general design of these differs very slightly from the first, and that only in matters of detail, the end guides for instance being done away with. A similar lift to the foregoing has been constructed to the design, and under the superintendence of, Messrs. Clark & Standfield, by Messrs. Cail & Company, of Paris, for the French Government on the Neuffossé Canal at Les Fontinettes. It is smaller in size, being adapted for barges of 250 tons. Masonry towers are substituted for the lattice girders in the La Louvière lift, and the end guides are dispensed with. The presses are formed by an internal copper lining $\frac{3}{16}$ inch thick, surrounded by weldless steel hoops stepped into each other, the whole being tied together by steel angle iron bolted together. The water is forced into these presses from the bottom.

HYDRAULIC HOISTS—LIFTS.

A cage raised and lowered on the top of a ram (the cylinder being sunk in the ground) is the simplest form of hoist. Provision in this case has to be made for a varying weight due to the altered condition of the load. As the ram rises, the head and pressure diminish, whilst the weight of the ram increases, as it is less and less immersed in the water. A counterbalancing weight is, therefore, required to lower the cage when empty, and to adjust the varying weights of the chain as the cage rises and falls, and also to balance the weight of the ram. The counterweight is usually attached to the chains connected with the cage, and passing over fixed sheaves at the top of the lift-framing. The amount of weight to be provided must be sufficient to balance the cage and the whole weight of the ram when at the top of the stroke, *minus* the weight of the chain which then assists the counterweight. When the ram

Fig: 1.



THE "OTIS" ELEVATOR.

Thos Kell & Son, Lith.

is at the bottom of the stroke, the counterweight must balance cage, ram, and chain, the weight of the ram being then less than when it was at the top of the stroke, owing to water surrounding it. It will be seen that where the weight of a direct-acting ram is counterbalanced, the ram is subjected to both tensile and compressive strains, according to whether the ram is being pulled by the counterweight or pushed by the water-pressure. If, on the other hand, the counterweights are omitted, the amount of water consumed to raise the load is greater in proportion to the useful work done.

Hydraulic power is finding a large field for useful employment in the direction of working house lifts. Until recent years the form of lift to which hydraulic power was chiefly applied was that for raising and lowering loads, either by a platform placed on the top of a direct-acting ram, or by a cradle attached to a chain or a wire-rope, either passing over multiplying sheaves on a ram in an hydraulic cylinder, or wound over a drum worked by a rotary engine. Hydraulic lifts or hoists were formerly chiefly used in railway goods-yards and termini, docks, &c. In more recent years, however, the field of application has been extended to offices, hotels, and private houses, where the height of the upper floors renders some mechanical appliance necessary.

THE OTIS ELEVATOR.

The low pressure of water companies' mains is capable of being utilised for lifts. A good form of low-pressure lift is that which is known as the "Otis Standard Hydraulic Elevator," manufactured by the American Elevator Company. The mechanical arrangements which are characteristic of this lift are shown in detail by Plate 12. The motor is a cast-iron vertical cylinder A connected by a tee C to a smaller cylinder B, the bottom of which rests in the water-chest D, connecting with the valve through the port E. The cylinder A is con-

nected with the valve through the port F. The valve is a piston valve with a rack attached to the top of the piston, and is worked by the sheave T, attached to the pinion shaft, and controlled by a hand rope S passing through the car. In the cylinder A is a piston G connected by means of two piston rods, which pass through stuffing-boxes N to a crosshead K. This crosshead rests in a double strap I, which holds the travelling sheave H, connected with the car by means of four independent wire cables, one end of each being fastened to a hitching block by means of fork rods. The other ends, after passing under the travelling sheave H, and over the overhead sheave R, are led, two on either side, to the bottom of the car, where they are attached to the ends of the safety platform upon which the car rests.

The piston and the car thus travel in opposite directions; the former, with its attachments, balances a certain proportion of the dead weight of the car. The rest of the dead weight is counterbalanced by cast-iron blocks L placed in the strap I. Owing to the sheaves H and R the car has a travel of twice that of the piston G (the travel of which is never more than about 30 feet), so as to retain the solid column of water underneath it by atmospheric pressure, when it is at the top of the cylinder. The motive power is usually the hydrostatic pressure from the elevation of a cistern, so that the pressure rarely exceeds 40 lbs. per square inch. The speed is usually 300 to 400 feet per minute. There are three pistons in the valve connected by a stem, the upper one being for the purpose of preventing the water from escaping through the valve cap at the top of the valve. The pressure on the bottom of this upper valve piston is equally on the top of the second piston, and enables the valve to be raised or lowered without effort.

The area of the cylinder A is made proportionate to the load to be lifted. The downward pressure is always constant on the piston G, but downward motion is impossible until the column of water which is underneath the piston G is allowed

to move by the opening of the valve. The exhaustion of the column underneath the piston G is effected by raising the valve piston until it occupies the space between the ports E and F, as in Fig. 2. This raising of the valve piston opens connection between the port F and the discharge pipe, enabling the column below the piston G to discharge, and the hydrostatic pressure on the top of the piston G to become effective in forcing the piston down to the bottom of the cylinder.

The column of water below the piston G will not fall away and discharge unless there is a pressure on the top of the piston, even if the piston G is at the top of the cylinder, as the column of water under the piston G is never more than 30 feet in height; and this column is sustained by atmospheric pressure. The available pressure is always the same throughout the entire stroke, for what is lost in head (when the piston G is near the top of the cylinder A) is balanced by the weight of the column which hangs to the bottom of the piston; and as the piston descends, and the head increases, the weight of the column underneath the piston decreases.

For lowering the car, the valve piston is lowered below the port F into the discharge, and thus the pressure (which is also in the circulating pipe B) acts under the piston G as well as on the top of it. The pressure being thus neutralised, the car descends by gravity, raises the piston G, and displaces the column of water on the top of it. This water passes through the port C into the tee, and being prevented by the greater pressure from going up the supply pipe, it passes through the circulating pipe B into the valve, back through the port F under the piston G, filling the cylinder A under the piston, as the piston ascends. The discharge of this water is prevented by the position of the valve piston, as shown in Fig. 3, and thus the water which was on the top of the piston G is led below it, ready to be discharged the next time the car is raised. The solid column of water thus acts on both sides of the piston, so that no action of the piston can take place without a displacement of water, which can only be produced

by a change of the position of the valve. All motion is stopped when the valve piston covers the port F (as in Fig. 1) without regard to the position of the piston G, for the column below the piston G cannot be discharged while the valve piston is covering the port F. Nor can circulation take place, because that same position of the valve piston prevents the flow of the water from the circulating pipe B under the piston G, the head in the supply preventing the water above the piston G from being forced up the supply pipe.

Attached to the piston G is a cast-iron apron, or follower, which automatically cuts off the discharge at port F, in the downward stroke of the piston. The discharge is cut off before all the water is exhausted from the bottom of the cylinder A, and, therefore, this water forms a cushion on which the piston seats itself gradually. To prevent the accumulation of air underneath the piston G, an air valve is attached to the piston by which the air passes through the piston to the top of the cylinder A, and then either passes out through the supply pipe or is exhausted by means of a jet cock M. When the travel of the piston G is suddenly arrested, the shock is overcome by means of a relief valve, connecting the water-chest D with the port F, enabling the water under the cylinder to communicate the shock through this valve to the column in the water-chest D, and circulating pipe B, on into the supply pipe. In case of a sudden stoppage of the piston G in an upward stroke, the shock finds vent through the port C up into the supply pipe, and is also overcome.

There are never less than four cables used, and the smallest size is half an inch diameter. The diameter decided upon in each case is such that any one cable shall have many times the necessary strength to do all the work. These cables are so attached that they receive an equal strain, and in case of the breaking of one, there is nothing to occasion the breaking of any of the others. The four cables are attached to the safety platform underneath the car, and are so arranged that the car will not work unless the strain on each cable is equal.

By this means the mere stretching of one cable makes it impossible to run the car until the stretch shall have been adjusted by means of the fork rod, by which it is attached to the hitching-block.

Under the car is a safety platform, consisting of hard wood faced with iron plates. At each corner is an iron shackle rod, to each of which a cable is attached. These shackle rods are fastened to an equalising bar underneath the platform, which is held by a pivot in the centre, and so long as the strain upon the two cables is equal, the bar will retain a horizontal position, but the stretching of a cable will allow the bar to leave its horizontal position, in either one direction or another, according to which end receives the greater strain. The shape of this equalising bar is such that, when it leaves the horizontal position, the forged projections of the bar come in contact with other forgings, which are a part of the wrought-iron rod that is extended from end to end of the safety platform on its underside. One of the forgings of this rod is a finger with toothed end. The normal position of this finger is just below a brass wedge which travels with the safety platform, and is held in place by means of a shoulder both on the top and side, and is thus prevented from falling out. The platform is grooved at either end to receive the hard wood slide on which the car travels. The jaws and ends of the safety platform are faced with heavy iron plates. The position of the wedge is between the guide and one of these jaws, and, from its shape, a pressing in of the wedge creates so great an amount of friction that the car cannot travel. The wedge is pressed into its place by the finger before alluded to, and that finger is in turn worked by the mere stretching of a cable. Each end of the safety platform is equipped alike, and the rod which passes underneath the platform connects the two ends, so that action at either end necessitates the pushing in of the wedges at both ends. These wedges cannot slip out of position, nor can the slides warp out of place, or

fail to be wedged. An adjustment and equalising of the tension of the cables which may have stretched, will at once remove the fingers which press in the wedges, and an upward motion of the car itself would at once release the wedges, owing to their shape. Downward motion is then possible, but it is impossible until the tension of the cables is equalised. It follows then that the heavier the weight in the car, the greater the power there is pressing in these wedges, and the teeth of the end of the finger, which comes directly in contact with each wedge.

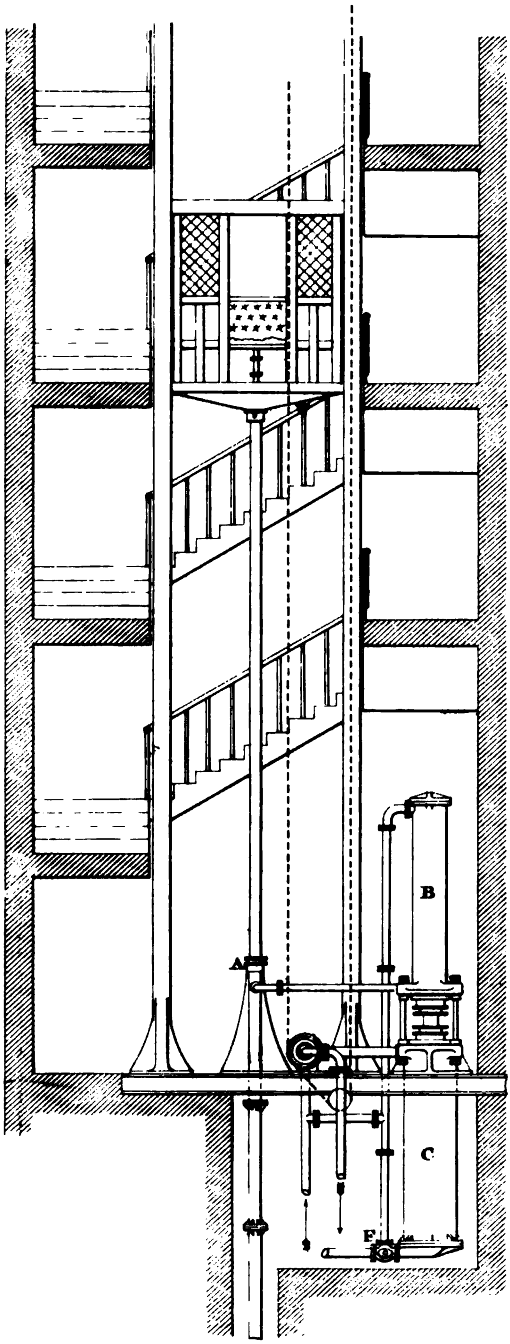
There is also a safety governor which has a separate attachment to the car by means of an independent wire cable. This passes through the governor, under a sheave at the bottom of the well in which the car runs, and back again to the side of the car where both ends are attached. The governor is made for whatever speed may be desired, and any speed in excess of that would cause it to act.

Messrs. Tommasi and Heurtvisé have devised a plan to balance the dead weights by means of a second hydraulic cylinder placed close to the lifting cylinder, and connected with it. The ram in this second cylinder is loaded so as to balance the lifting ram and cage when at the bottom. It has a larger area but shorter stroke than the lift-ram, and is continued of the same diameter, through a stuffing-box, to another cylinder above it. The pressure in this latter cylinder, acting on the ram, balances the lifting ram in the lifting cylinder with its cage when at the bottom. Counterweights serve to further balance the lifting ram as it rises, so that the pressure required to be applied to the lifting ram is only that which is necessary to raise the people in the cage, and the lifting ram is (as it should be) always in compression.

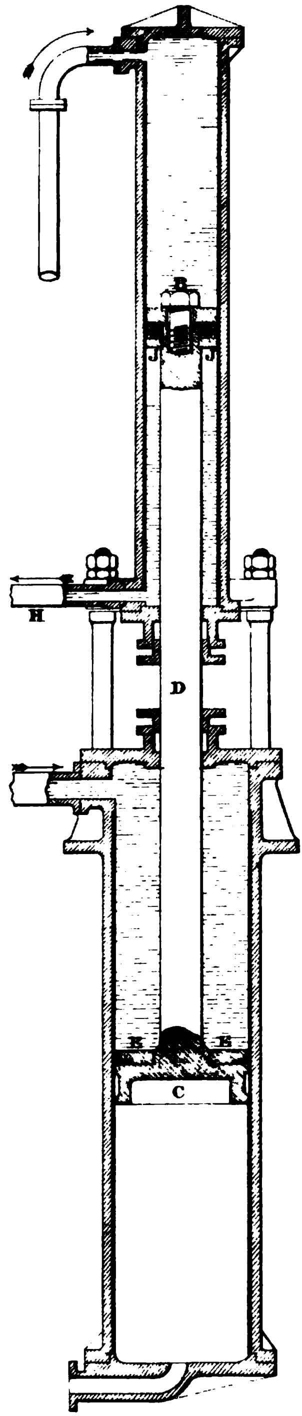
Mr. Ellington has designed an hydraulic balance lift for low pressures, which was explained to the Institution of Mechanical Engineers, and is shown by Plate 13.

As in the previously described lift, the ram is always in compression, and the dead weight of ram and cage at bottom

HYDRAULIC BALANCE LIFT.



Scale 1 to 96.



BALANCE CYLINDER.

Scale 1 to 32.

Thos Kell & Son, Lith.

of stroke is balanced by means of a second cylinder B (with piston 11 inches diameter and 8 feet 2 inches stroke), which is in hydraulic connection with the lifting cylinder A (with ram $3\frac{1}{2}$ inches diameter and 50 feet 6 inches stroke). The piston B has the pressure always on the upper side. The piston rod D of the second cylinder B is continued into a third and larger cylinder C, with piston $21\frac{3}{4}$ inches diameter and 8 feet 2 inches stroke. The diameter is calculated to give an annular space EE sufficient to lift the weight of the people in the cage, and to overcome friction.

When the cage is to be raised, water is admitted to the top of the third cylinder C, and the pressure exerted by it on the annular space EE, together with the constant pressure on the piston of the upper cylinder B, form a continued pressure which is exerted on the annular space JJ of the upper piston B, and is transmitted through the pipe H to the ram of the lifting cylinder A. The ram rises, and in doing so causes an increasing dead weight to come into play. The pistons B and C simultaneously fall, and in doing so receive an increasing weight of water upon them, which balances the loss of head due to the rise of the lifting ram. The cage is lowered by opening the exhaust from EE (the pressure remaining, as before stated, on the top of the piston B), and as the lifting ram descends, it transmits the pressure due to its weight and that of the cage to the annular space at the bottom of the piston in the second cylinder B, and overbalances the weight of the pistons, *plus* the constant pressure on the piston B. The dead weight of the lifting ram in its descent diminishes, whilst the counter-balancing pressures on the pistons in the cylinders B and C also diminish, owing to the displacement of (and consequent reduction in the weight of) the water above them both, thus preserving the same equilibrium in the descent of the cage that was preserved in its ascent. By means of the cock F water can be admitted under pressure to the underside of the piston in the cylinder C, thus relieving the pressure at JJ in the upper cylinder, and allowing water from the top of this

cylinder to flow past the packing leathers to the bottom of this cylinder, to make good any leakage or waste. By closing the cock F, whilst the cage descends, and whilst the piston C rises, a vacuum is caused, which can be utilised to raise weight in the next ascent of the lift, or to raise an empty lift without any power being exerted. The net load raised was 8 cwts., and the water-pressure was 33½ lbs. per square inch. The speed of ascent was found to be 35 feet per minute with the cage loaded, and 138 feet per minute when it was empty. The empty cage descended at the rate of 47 feet per minute. Where the lift is connected with a high-pressure water main (that is, of 600 or 700 lbs. pressure per square inch), the water for the balance is proposed to be taken from and returned to a tank.

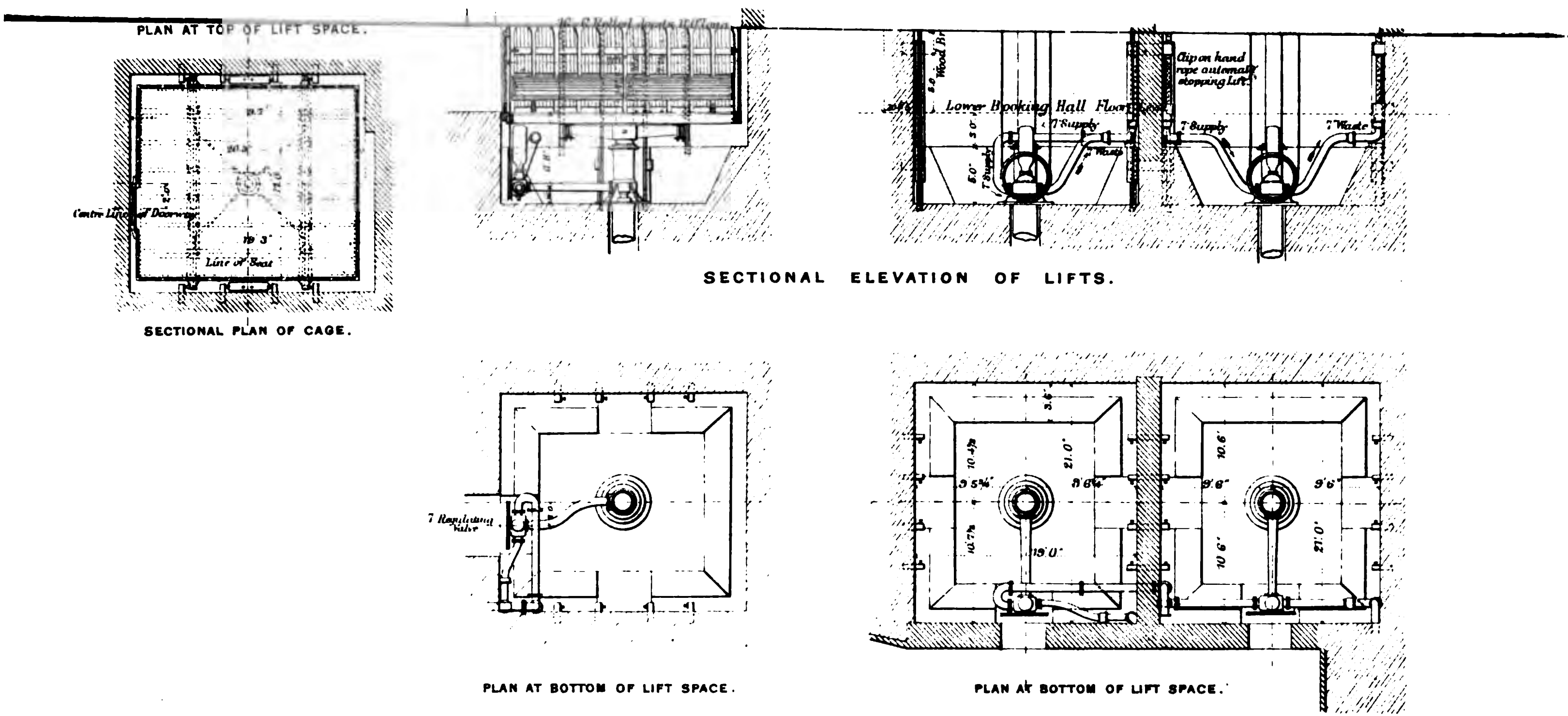
In the Paris Exhibition of 1878, Mr. Samuel Chatwood exhibited hydraulic lifts with balancing apparatus.

MERSEY RAILWAY LIFTS.

The railway under the river Mersey (which was constructed by the late Sir James Brunlees and Sir Douglas Fox, and was opened by the Prince of Wales in January, 1886), has at each extremity hydraulic lifts for conveying passengers and their luggage from the deep underground stations at James Street and Hamilton Street to the daylight stations on the street level above. Particulars of these lifts were given in a paper read at the Institution of Civil Engineers by the late Mr. Rich (of the firm of Easton & Anderson, their constructors). Plate 14 shows the arrangement. The lifts at the James Street station have a stroke of 76·6 feet, and at the Hamilton Street station 87·7 feet. At each station there are three lifts independent of one another, each being capable of raising one hundred passengers at a time. The maximum load due to passengers is taken at 15,000 lbs. The lifts are direct acting, with rams of hollow steel 18 inches in diameter,

MERSEY RAILWAY HAMILTON STREET STATION.

ARRANGEMENT OF PASSENGER LIFTS AT BIRKENHEAD.



PLAN AT TOP OF LIFT SPACE.

SECTIONAL PLAN OF CAGE.

SECTIONAL ELEVATION OF LIFTS.

PLAN AT BOTTOM OF LIFT SPACE.

PLAN AT BOTTOM OF LIFT SPACE.

Thos Kell & Son, Lith.

with balance chains and counterweights. The ascending cage is 19 feet 6 inches long by 16 feet 6 inches wide and 8 feet 10 inches high. They are worked by low pressure water derived from a tank, aided by water pumped by steam-power direct into the lift supply-pipe. The tank to give the water-pressure is placed at the top of a block of buildings at each end of the tunnel. It is 15 feet 6 inches in diameter, 9 feet deep, and contains 10,000 gallons of water, representing storage for twelve journeys. The water is discharged by the descending cages into an underground tank, from which it is pumped back to the high level tank, the effective head in which is 176·5 feet at James Street, and 164 feet at Hamilton Street.

The several lifts are contained in rectangular vertical shafts, 21 feet long and 19 feet wide, partly excavated out of the solid red sandstone, and partly in walls of brickwork. In the centre of each lift space, a boring has been carried vertically beneath the floor to a depth of 75 feet to receive the lift cylinders, which are of cast iron, 21 inches internal diameter, and 1¼ inches thick, bolted together in 12-feet lengths. The rams are 18 inches outside diameter, and ½ inch thick, constructed of mild steel tubes in lengths of 11 feet 6 inches, and connected together by internal screwed ferrules 6 inches long and 15¾ inches internal diameter. The cage is guided and kept in position by four cast-iron guide brackets (of a V-shape) 16 inches long. From the side girders two chain pulleys, 4 feet 8 inches in diameter, are suspended. Between each pair of them is a counterweight weighing 7,620 lbs., capable of being increased by smaller weights of 90 lbs. each to balance the lift. A large self-acting flap-valve admits water automatically to the lift cylinder from the exhaust, if the starting valve is closed too suddenly during the ascent of the lift. The stroke of the hand-rope, from full pressure to full exhaust, is 9 feet, which enables the starting and stopping to be effected quietly. Three 7-inch mains descend to each lift from the bottom of the supply tank, with the necessary valves to control the service. The speed is about

2 feet per second, and the average journey is accomplished in from thirty to forty seconds. The three lifts at each station are capable of working simultaneously, raising three hundred passengers in about a minute. The total cost of the six lifts with all machinery was about £20,000.

CITY AND SOUTH LONDON RAILWAY LIFTS.

In connection with the City & South London Electrical Railway, hydraulic lifts are employed to provide communication between the underground platforms and the street above, as the line passes under the Thames between Stockwell and the City. There are six stations on this line of railway, and at each of these there are two lifts (independent of each other) working in a vertical shaft 25 feet in diameter and of varying depths. The cages are semicircular, being about 22 feet long, 9 feet wide, and 11 feet high, access to them being obtained by Bostwick folding gates. The lifting machinery is fixed vertically against the sides of the shafts. The cylinders have multiplying power of 3 to 1, and the lifting and lowering are effected by four steel ropes attached to the cage, two other ropes being connected to counterweights, these ropes passing in the usual way over sheaves carried by girders at the top of the shaft. The water is conveyed at a pressure of 70 atmospheres from a pumping station at one end (the Stockwell) of the line, in pipes laid in the subway, and supplies the power to the several stations throughout the 3½ miles of railway. One accumulator is placed at the pumping station, and one at the station at the Elephant and Castle. The exhaust water from the lifts passes into an air vessel before conveyance to the return water-pipe. These hoists and the machinery were constructed by Sir William Armstrong, Mitchell & Co., Mr. Greathead being the Engineer to the Company, Sir John Fowler and Sir Benjamin Baker being the Consulting Engineers.

ELEVATORS OF THE NORTH HUDSON COUNTY RAILWAY.

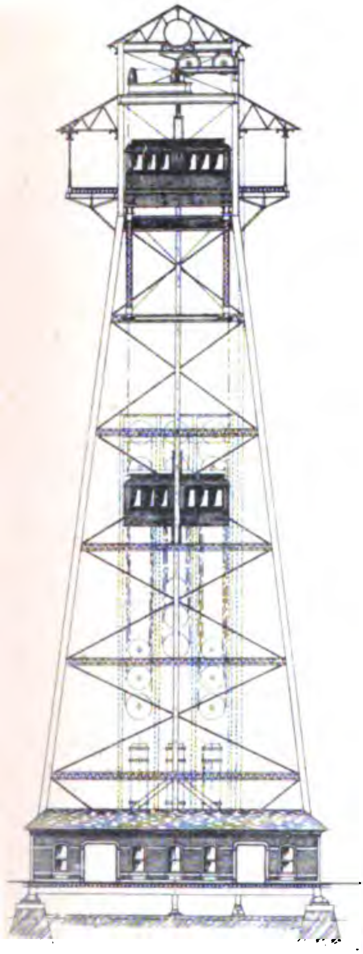


Fig: 1.

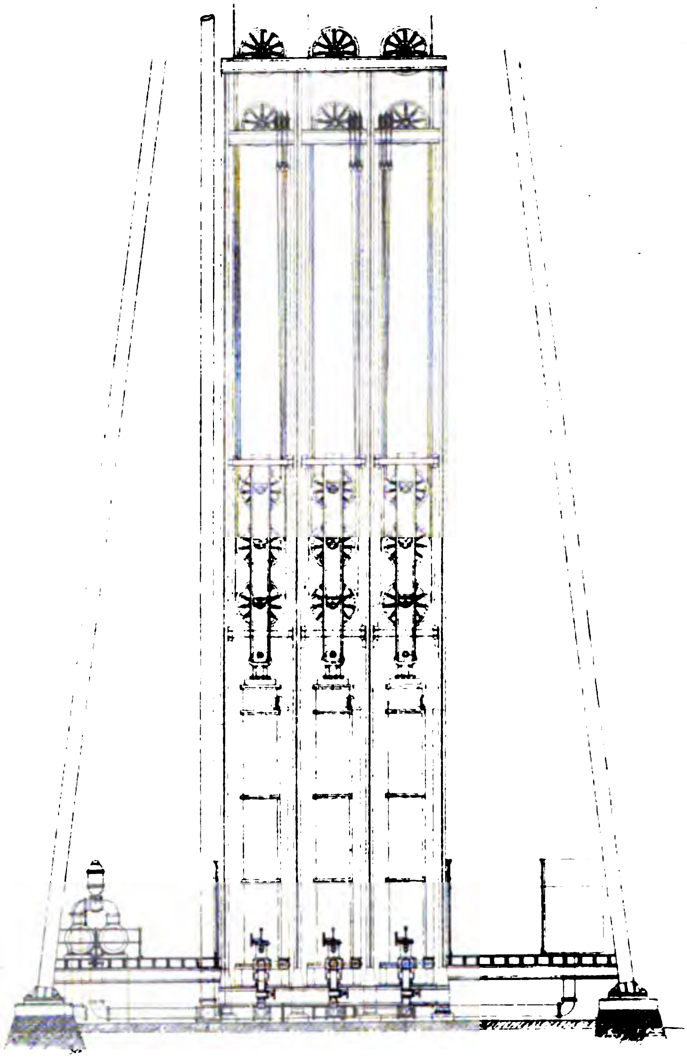


Fig: 2.

West, Newman Photo.

NORTH HUDSON COUNTY RAILWAY ELEVATOR.

The largest elevators in the world for passenger service are those that have been erected for the North Hudson County Railroad. They are designed upon the principle of the ordinary Otis Elevators, which have been already described, the details having been specially planned for work of such magnitude. These elevators, three in number, are situated on the west shore of the Hudson River. Their purpose is to raise passengers from the ferry boats which run from Forty-second Street, New York City, to the high level stations, and the road on the top of the cliff, which, at the point referred to, is very steep and tedious for pedestrians.

Plate 15, Fig. 1, is the elevation of the tower that has been built at the ferry landing. The upper platform of this is connected with the cliff by a double track viaduct about 900 feet in length, built in six spans, and carried on six towers. Fig. 2 shows the elevation of the cylinders.

The elevators were manufactured by Messrs. Otis Brothers & Company, of New York (American Elevator Company, London), and each machine is capable of lifting 130 persons to a height of 145 feet at a speed of 200 feet per minute. The hydraulic power is derived from a closed overhead tank, in which there is also a constant pressure of air, giving at the foot of the tower, therefore, a greater pressure than that due to the natural head of water. As fast as the water is used for the service of the elevators it is pumped back again into the closed tank by compound Worthington Pumping Engines. The tank has a capacity of 10,000 gallons, and the waste tank at the foot of the tower is of a similar size. There is an additional closed tank at the foot of the tower, of 1,200 gallons capacity, in which also a pressure of air is retained, and from which the elevators obtain their immediate supply.

As will be seen from the drawing, there is little difference

between these large elevators and the Standard Otis machine. The cylinders are larger, and the gear is somewhat higher than usual, being six to one, with a number of multiplying sheaves. The total travel of the pistons in the motor cylinders is, therefore, one-sixth of the total car rise. Each elevator is fitted with two of the Otis Governor Safeties instead of one as is ordinarily employed.

The car counterbalance is distributed, a part of it being accounted for by the weight of the travelling sheaves and wrought-iron frame straps in which they run, to which also a certain amount of cast-iron balance is added; and part of it being independent counterbalance weights.

The operating valves are too large to be manipulated by the ordinary hand rope. The valve is, therefore, controlled by means of an auxiliary hydraulic cylinder, operated in turn by a smaller valve, worked by the attendant in the car by means of a lever and ropes. This operating valve is so arranged that the stroke of the main valve is proportionate to the distance through which the attendant moves the lever in the car. The speed of the elevator is, therefore, even more perfectly under control than is the case with small machines where a hand rope is attached directly to the main valve.

The water pressure employed is 180 lbs. to the square inch. The cylinders and all working parts were tested to 500 lbs. per square inch. Each motor is 38 inches in diameter, with flanges 50 inches in diameter and 3 inches thick, the main wall of the cylinder being 2 inches thick. The sections are bolted together by 24 bolts. The head and base of the cylinder are so constructed that a prolonged apron stop attached to the piston cuts off the supply or discharge water without shock, in the event of the operator, through carelessness or other cause, omitting to control the machine at the top or bottom of its rise.

The cars are fitted with entry doors at one end and with exit doors at the other, the doors being double and 6 feet wide. Each car is suspended in a steel frame, formed of

channels, angles, and plates. Ample ventilation is provided by windows that can be opened. Two guides only are used for each passenger car. The type of safety used is one patented by the Otis Company and known as the Triple-Grip safety. It consists of a triple jaw, which embraces both guides simultaneously on three sides. It is attached to the main framework of the car, and will act in the event of the car descending with excessive speed from any cause whatever. This safety is operated either by the breaking of one of the lifting ropes, or by the Otis governor already described.

The elevators have fully met the requirements of the service for which they were intended, by raising the passengers from the ferry boats as fast as they can be landed, one elevator being down again to receive passengers by the time the last of the three is loaded to commence its upward journey.

LIFTS FOR SUBWAYS.

Hydraulic power has another new field for utilisation in the direction of working lifts for subway traffic, both vehicular and passenger. In many cases where the construction of a bridge to convey traffic over a river is objectionable, a subterranean communication has been difficult to make, owing to the approaches to the subway being impracticable. Mr. Greathead and Sir William Armstrong, Mitchell & Co., have given much attention to the question of providing hydraulic lifts, which would enable the long and expensive approaches to a subway to be dispensed with, and which would at the same time meet uninterruptedly the demands of a large vehicular traffic.

An example of this is shown by Fig. 27, which represents the arrangement of hydraulic lifts that was proposed to be placed on Tower Hill and on the Surrey side for giving access to and from a subway under the Thames. Two series of cages or compartments (which were to be well lighted) were

arranged to admit of free ingress and egress for the traffic going in both directions. One series was for lowering the traffic going southwards through the subway, and the other was for raising the traffic coming northwards from the subway. Each of the compartments was of such a size as to take either the largest vehicle and four horses, or a tramway car and horses, or two smaller vehicles and their horses. The working of the lift is as follows:—A vehicle arriving would pass into, say, the first of these large compartments, and be lowered immediately to the roadway below. The vehicle following would pass into the next compartment and be lowered. By the time the last of the series of lifts or

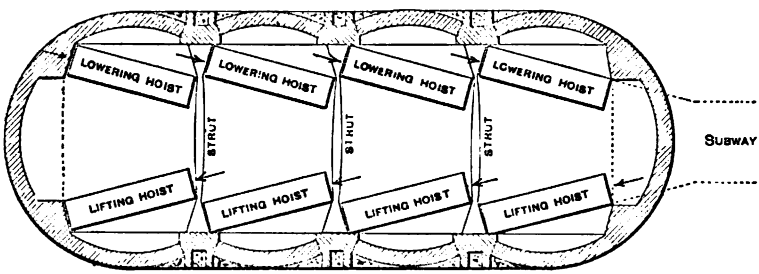


Fig. 27.

compartments had gone down, the first would be back again at the surface for a repetition of the operation. The traffic would thus pass down continuously on that side, whilst a similar series of lifts at the other end would in a similar way take it up. The cost of the whole communication, including subway, shafts, lifts, subway for foot passengers, &c., in complete working order, was estimated to be £280,000. While a similar communication with inclined approaches would cost probably three times as much, and would involve the demolition of buildings and the displacement of population.

A subway can thus be approached at whatever depth it might be below the surface, and without the difficulty attending approaches with steep gradients, provided the number of lifts be proportioned to the traffic. The advantages

of such a system of lifts are apparent. The continuity of traffic is not interrupted as in the case of a ferry or an opening bridge. No inclines have to be surmounted. Owing to the distribution of the traffic through a series of cages, the working expenses of lifts are in proportion to the traffic, whereas when large platforms are used, as hitherto, capable of taking a considerable volume of traffic, the working expenses are frequently out of proportion to the traffic, because at slack times the large platform is set in motion for one small vehicle. There is a great saving in first cost of communication compared with the cost of a subway having inclined approaches, or with a subway having a large platform. By the multiple-lift system struts can be put between the deep walls of the shafts (as shown in Fig. 27), which would be impossible if the single-lift system were employed. An arrangement of lifts like these effects a great saving of time to vehicles passing from bank to bank of the river. For instance, the lifts in the case shown by Fig. 27 would take half a minute to go down and the same to go up, and assuming a vehicle to travel at three miles an hour through the subway it would only take five minutes from bank to bank.

The cheaper means of making communications under rivers which this system of lifts affords, appears to open out a very important extension of the application of lifts. In some cases any additional communication has of necessity to be cheaply effected. The amount, or nature, of the traffic in many cases is such as to require that only a small outlay is incurred to make the work remunerative. The Glasgow Harbour Tunnel, for vehicular and foot traffic, now in course of construction under the Clyde, on Mr. Greathead's system, is to be approached by multiple-lifts on each bank of the river.

HYDRAULIC RAM.

The hydraulic ram is a machine of great simplicity, which enables the power of a fall of water to be used directly to raise water to a height greater than the fall.

The principle of its action is the elementary dynamic law that the energy of any body in motion will be absorbed, and consequently the body will be brought to rest, by any resistance which opposes its motion if such resistance acts through a sufficient distance.

This principle affords a particularly suitable way of using the power of a fall of water, when the work required to be done is pumping water or compressing air, as the work to be done affords a suitable resistance to absorb the energy of a mass of water. The mass of water is provided by the contents of a pipe of suitable length conveying water from the source of supply to the machine, which is placed in a tail-race. The machine, as ordinarily constructed for small quantities of water, is an iron box in which are two valves, usually called the pulse or waste valve, and the discharge or delivery valve. An air-vessel is mounted over the delivery valve, and the delivery pipe takes off from this air-vessel. Through the waste valve the water freely escapes into the tail-race for a short time (usually between one and two seconds). The contents of the pipe during this time acquire a certain velocity, and when the pressure on the valve caused by the head due to this velocity is sufficient to raise it, it does so and closes the valve. The water, having then no other outlet but the delivery valve, opens this valve and flows through it against whatever pressure there may be in the air-vessel, until the resistance offered by this pressure has absorbed all the energy of the column of water and has so brought it to rest. A certain reflux of the water then takes place, which opens the waste valve, and the cycle of operations is repeated. The water so pumped into the air-vessel

is discharged through the delivery pipe in a continuous stream.

Machines made in this manner work very well when suitably proportioned, but it has not been found practicable to use waste valves larger than 4-inch diameter, as the shutting is accomplished with very considerable violence. This is easily understood when it is considered that, even if it were closed by a pressure which continued constant, its velocity would be at its maximum when the valve shuts, and in the actual case the pressure continually increases in amount, so that when the valve shuts, it is many times as great as when the valve began to move.

It has been attempted to reduce this violence by checking the speed of the valve by balance weights, springs, and similar contrivances; but it is evident that it must be very detrimental to the efficiency of the machine to delay the shutting of the valve, because the narrow orifice of the nearly closed valve checks the flow of the water, and so wastes the energy which has been imparted to it in the same way as by the slow closing of a sluice valve, all the energy of the water flowing in a main may be wasted, and the water may be brought to rest while closing the sluice. This difficulty has, however, been lately removed by the device, due to Mr. H. D. Pearsall, C.E., of providing a space into which some of the water flows during the closing of the waste valve. The velocity of the water escaping by the waste valve is not then increased while the valve is closing, and the valve may, consequently, be closed as slowly as desired, and so without violence; and thus it became practicable to make very much larger valves.

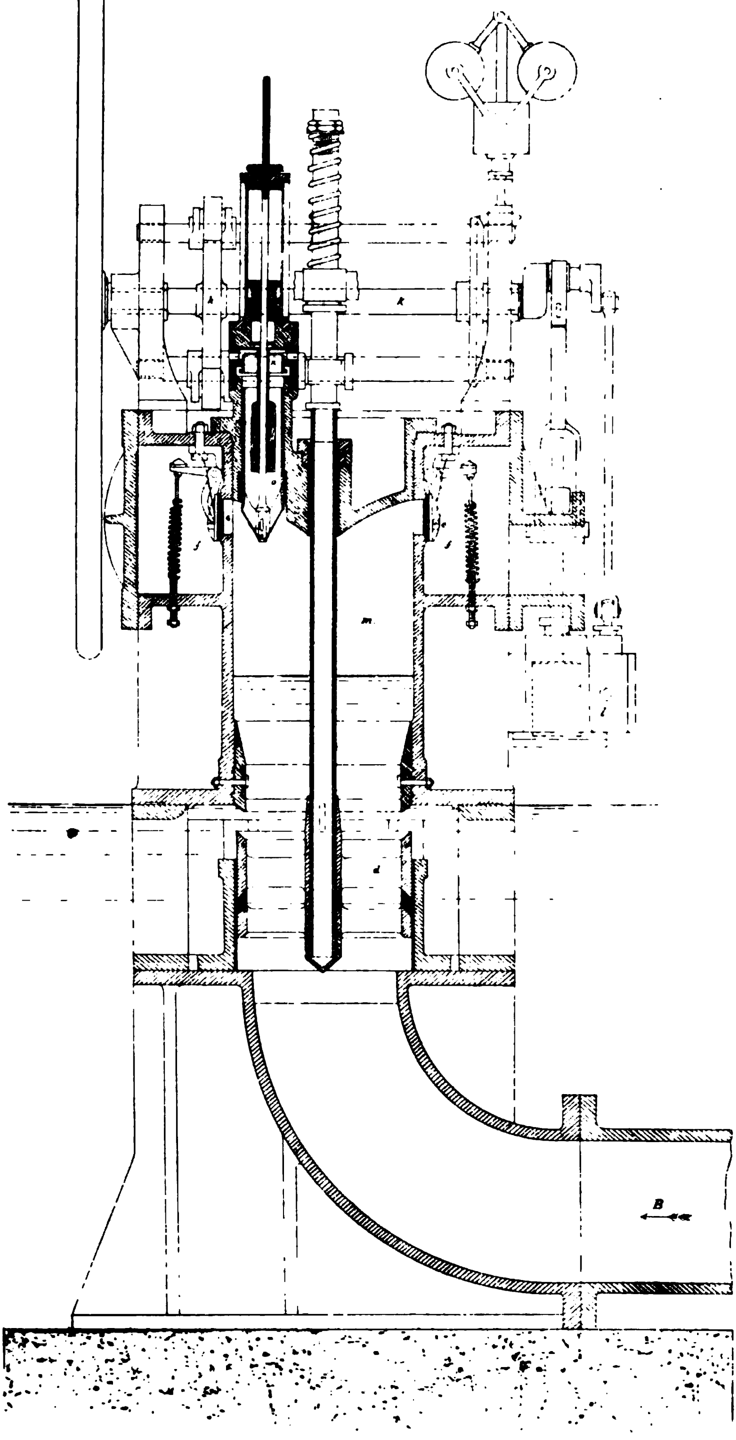
The special object Mr. Pearsall had in view was the construction of rams which might be available for the largest engineering works; but this had hitherto not been attained. The difficulties, however, appear now to have been overcome by means of this and various other improvements which have been introduced by him.

PEARSALL'S HYDRAULIC ENGINE.

Plate 16 shows a sectional view of Pearsall's hydraulic engine, of which the following is a general description:—In place of the waste valve D of the ordinary hydraulic ram, there is an annular sliding valve *d*, and in order that the opening and shutting of this valve should be made exactly in the pre-determined times, it is moved by a cam *h* which is on a shaft *k* turned by a small auxiliary engine *l*. The cam is so formed that the motion of the valve is dead slow at the instant of shutting, and so closes without any concussion. When the valve *d* is open, the water escapes freely through it into the tail-race, and the water column in the flow pipe B acquires velocity and momentum. As the valve *e* closes, this outlet is cut off, but the flow is not interfered with, as the water can rise freely in the chamber *m* which is full of air, the air escaping as the water rises through the valve *n*. The quiet, slow, closing of the valve, therefore, does not cause any loss of useful effect. The size of this chamber is so proportioned that it is not filled with the water entering it until a short time after the main valve is quite closed. The air valve *n* is enclosed in a tube *o*, the depth of which projecting into the chamber can be regulated by a screw. If it is allowed to project a little into the chamber, the layer of air in the chamber above the edge of this tube cannot escape through the air valve. If, on the contrary, the tube is raised till its edge is flush with the roof of the chamber all the air escapes through valve *n*. Supposing the tube to be in the latter position, the water on filling the chamber opens the valves *e* and flows into the space *f* which communicates with a larger air vessel (not shown) from which the delivery pipe takes the water to an elevated reservoir. The air valve *n* is closed by the flow of a small part of the water up the tube *o* past a float attached to the air valve.

Usually the position of the end of the tube O is a little below the roof of the chamber, and then a little air is com-

PEARSALL'S HYDRAULIC ENGINE.



West, Newman Photo.

pressed by the column of water and enters the air-vessel with, or rather in advance of, the water. The object of this is to keep the air-vessel replenished with air, and for use in the little auxiliary engine *l*, which, as already stated, moves the main valve *d*.

The flow of the water past the valves *e* into the air-vessel against the pressure existing there, gradually retards and finally arrests the column of water in the pipe B. This is accomplished without any internal blow, and without any rise of pressure exceeding (except by a few lbs.) that in the air-vessel. This has been proved by indicator diagrams taken by an ordinary indicator from the chamber *m*.

The water having, by this static resistance, been brought to rest after a considerable interval of time, the main valve is again opened, the air valve falls open, and the chamber *m* is emptied of water and again filled with atmospheric air through this valve.

Engines of a similar type have been used also for compressing air. This is accomplished by lowering the tube O still further below the roof of the chamber, and so preventing the escape of a larger proportion of the air which was in the chamber. In compressing air the chamber *m* is larger or smaller, so as to hold more or less air, according to circumstances—chiefly depending on the amount of the fall. The quantity of air is in all cases regulated with any degree of exactness by the position of the tube O.

It appears highly probable that such engines will be used in future for very large water powers, taking the place of a combination of water wheels with pumps. It will be an advantage to substitute one such simple machine for the combination of two machines, and as it involves only one transformation of power instead of two, a much higher efficiency results. The efficiency actually obtained has been over 70 per cent. in pumping water. In compressing air the difference is even more striking, as these machines have given an efficiency of over 80 per cent.

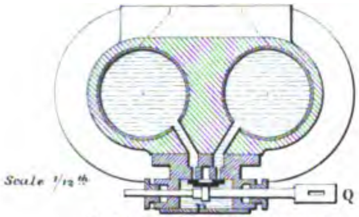
In the *Transactions of the American Society of Engineers*, Mr. Weston gives the results of some useful experiments which he made to ascertain the effect produced by the sudden closing of valves against water flowing in pipes. Lines of pipes from 1 inch to 6 inches in diameter were laid above ground, and an air-vessel was provided which could be connected or disconnected as required. The supply was drawn from a 24-inch main by a 6-inch pipe. The average static pressure in the pipe was 70 lbs. per square inch. In the first series of experiments the water flowed through lengths of pipes of different diameters thus:—111 feet of 6-inch pipe, 58 feet of 2-inch pipe, and 99 feet of $1\frac{1}{4}$-inch pipe, to a 1-inch outlet pipe, with a $\frac{1}{4}$-inch orifice. In this case the velocity was 0·15 of a foot per second in the 6-inch pipe, and 5·36 feet in the 1-inch pipe. Upon closing the orifice (which was effected in 0·16 of a second) the force of the ram in lbs. per square inch was 129·2 lbs. in the 1-inch pipe, 127 lbs. in the $1\frac{1}{4}$-inch pipe, and 14·5 in the 6-inch pipe. At the dead end of a separate $2\frac{1}{2}$-inch branch-pipe (leading out of the 6-inch pipe at a distance of 300 feet), the force of the ram was 18·8 lbs. With orifices of $\frac{1}{8}$, $\frac{3}{16}$, $\frac{1}{4}$, and $\frac{5}{16}$ of an inch, and with velocities of 1·06, 2·57, 5·36, and 6·75 feet per second, the rams in the 1-inch pipe exerted a force respectively of 26·9, 72·8, 129·3, and 158·7 lbs. per square inch. In the 6-inch pipe, with $\frac{1}{4}$-inch and $\frac{1}{2}$-inch orifices, and with velocities of 0·15 foot and 0·53 foot per second, the rams exerted a force of 14·5 and 51·7 lbs.

Mr. Weston made another series of experiments on an extension of the 6-inch pipe, comprising 182 feet of 6-inch pipe, 66 feet of 4-inch pipe, $3\frac{1}{2}$ feet of $2\frac{1}{2}$-inch pipe, 1 foot of 2-inch pipe, $6\frac{1}{2}$ feet of $1\frac{1}{4}$-inch pipe, and 6 feet of 1-inch pipe. With the $\frac{1}{4}$-inch orifice, and with a flow varying from 0·15 of a foot to 5·39 feet per second in the 6-inch and 1-inch pipes respectively, the ram exerted a force of 4·8 lbs. in the former, and of 66·7 in the latter. In the 1-inch pipe, with orifices of from $\frac{1}{8}$-inch to $\frac{1}{4}$-inch, the force of the ram increased from

PUMPING ENGINE KNOLL COLLIERY.

PLATE. 17.

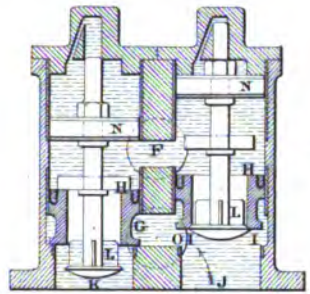
Fig: 2.



Scale 1/12th

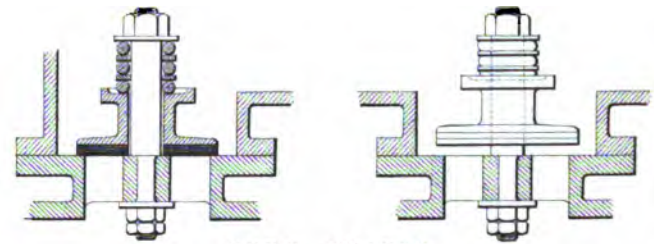
PLAN OF ENGINE VALVES.

Fig: 3.



SECTION OF ENGINE VALVES.

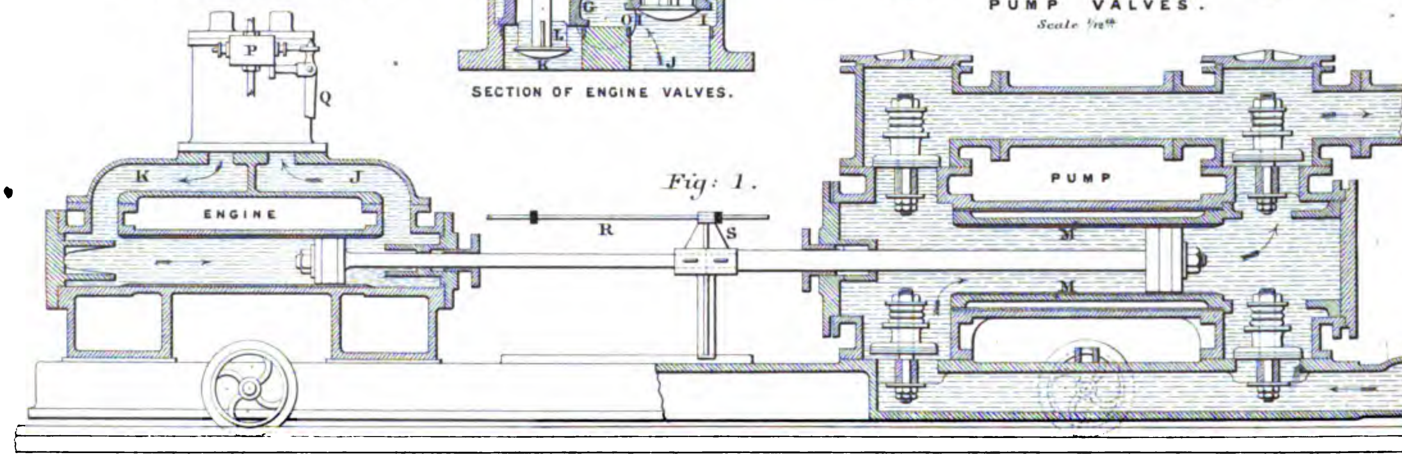
Fig: 4. *Fig: 5.*



PUMP VALVES.

Scale 1/12th

Fig: 1.



LONGITUDINAL SECTION.

Scale 1/24th

Inches 12 6 0 1 2 3 4 5 Feet

Thoˢ Kell & Son, Lith.

15 lbs. to 177·5 lbs. per square inch. In the 2½-inch pipe, the force of the ram was 22·2 lbs. with a ¼-inch orifice, and 183 lbs. with a 1-inch orifice. This latter was reduced to 106 lbs. when the pipes were in connection with the air-vessel. In 6-inch pipes the ram (with a ¼-inch orifice) exerted a force of 4·8 lbs., and with the 1-inch pipe 80·1 lbs. The latter was reduced to 65·6 lbs. when the air-vessel was connected.

PUMPING ENGINES.

At the Institution of Mechanical Engineers in 1880, Mr. Davey described a water-pressure pumping-engine (shown by Plate 17) which had been designed by him for the Knoll Colliery, Nuneaton. It was used to clear the water from a long working to the dip at an inclination of 1 in 6. The engines were specially designed to be very portable, and to occupy a very small space. They were in duplicate, each having a power cylinder 6¼ inches diameter, and 2 feet 6 inches stroke, working direct on a pump plunger 8¾ inches diameter, working at 12 double strokes per minute. By means of the liner M the diameter of the cylinder can be increased. When the liner is in position (as shown) the pump has a diameter of 8¾ inches. When it is withdrawn, a piston with a diameter of 12¼ inches can be employed, by which the capacity of the pump is doubled. The engine can then pump double the quantity of water to half the previous height, which is the arrangement employed until the water is cleared to half the depth of the workings. The water-pressure is supplied to the engine under an effective head of 450 feet, and it is transmitted through about 2,000 feet of 5-inch pipe. Each engine pumps 150 gallons per minute to a height of 150 feet, through 800 feet of 7½-inch pipe. The engine and pumps are placed on wheels, by which their position can be altered with respect to the water level.

The valves are shown by Figs. 2 and 3. The top orifice F

(Fig. 3) is the inlet, and the bottom orifice G is the outlet. The pipes J and K form the communication to the two ends of the engine-cylinder. The outlet valves HH are annular gun-metal pistons working vertically, each having two valve-beats, one on the inner edge I, and one on the outer edge O, of its bottom face. As this valve descends, the outside beat closes the communication to the outlet pipe, whilst the inlet valve L (rising against the inner beat) closes the supply. The inlet valve is an ordinary single beat mushroom valve with its spindle projecting, and attached to a piston N. The bottom face of this is constantly under the head in the pressure pipe, whilst the top face is exposed alternately to the head in the pressure pipe, and to the pressure in the outlet pipe, by means of a small gun-metal slide-valve P (Fig. 2), actuated by a lever Q, and tappet rod R (Fig. 1). If the exhaust valve is closed, and the pressure valve is opened (as on the left-hand side of Fig. 3), then the pressure valve L in closing rises up against the annular exhaust valve H, and lifts it, opening the exhaust orifice G. The valves are now in the position shown on the right-hand side of Fig. 3. The arm S (attached to the crosshead of the engine) strikes the tappet towards the end of the stroke, and pushes the slide valve over, by which the top of the right-hand valve piston is open to the head in the pressure pipe, and that of the other to the outlet. The main valves are thus reversed; the right-hand piston being under equal pressure top and bottom, the pressure on the top of the annular valve H forces it downwards, carrying the pressure valve L with it. When the valve H has come down on its beat O (closing the exhaust orifice), the valve L continues to descend under the pressure above it, and opens K to the pressure, as on the left-hand side of Fig. 3. On the other side the ascending piston causes its inlet valve to close and its outlet valve to open. By this arrangement water cannot pass through the valves unless it has performed its work, as the exhaust and pressure valves can never be open at once. The avoidance of a sudden

arrest of the flow of pressure water is thus effected. It was found that the efficiency of the engine was 65 per cent.

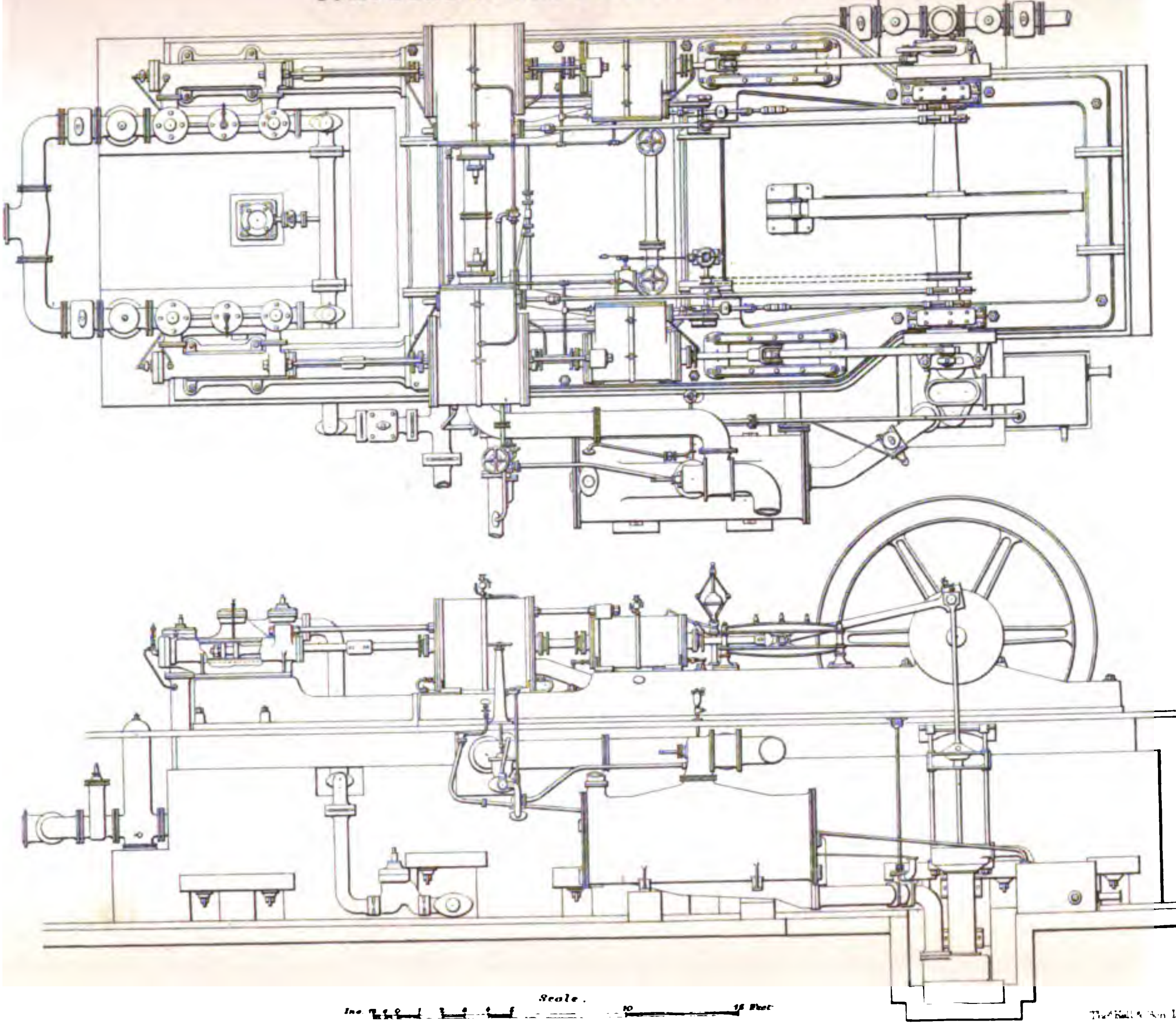
Where the water-pressure is great, or where the water is dirty, plunger valves are used, as any form of slide valve, or piston valve, is open to objection. If slide valves have to work under high pressures or in dirty water, a good combination of materials is found in lignum vitæ slides working on brass faces.

Herr Pfaehler employs water at the Sulzbach Altenwald Colliery, near Saarbrücken, to transmit the power from a steam-engine at the surface to actuate pumps at the bottom of a shaft 306 yards deep. The steam-engine has a cylinder 53 inches in diameter, and 61·5 inches stroke, connected with pressure plungers 9 inches in diameter and the same stroke. These plungers are brought into connection with an underground pumping-engine, consisting of four pressure pumps, with plungers 6 inches in diameter and 66 inches stroke, arranged in pairs, and put in motion alternately by the surface plungers. Between each pair of plungers (which are connected by a crosshead) is placed the working plunger of one of the mine pumps. The engine at the surface transmits the effort of each plunger through its rod tube to the corresponding pair of pressure pumps under ground, and this actuates the working plunger connected with it, either drawing or forcing water, the other pair acting conversely. The water is forced into an air-vessel, and thence through the rising main in one lift to the surface, the power supplied by the descent of water in one column being nearly sufficient to effect its return in the other. The tubes were proved to 100 atmospheres. The working pressure on the underground pumps (due to the difference between their areas and those of the pumps at the surface) is 50 atmospheres, and the hydrostatic head in the rods is 27 atmospheres. The total working pressure, including friction, is 77 atmospheres, or about 1,155 lbs. per square inch. The engine is worked at a speed of 10 double strokes per minute, the delivery of water

being continuous. Careful observations were made in order to ascertain the work absorbed by the friction of the different parts of the machinery, and it was found to be from 25 to 29 per cent. of the total power developed. The effective work of the pumps, at 10 double strokes per minute, was 100 HP, and the indicated HP of the engine, with a mean pressure of 20 lbs. per square inch on the piston, was 136 HP, which gives a combined efficiency of 75 per cent.

The first hydraulic pumping-engines were high pressure, with plungers at each end of the pistons, and in a direct line with them. The original valves were made in the first place with flat faces of cast iron, but these were very soon cut. Faces of steel were then tried, but they also did not stand for any length of time, and eventually mitre-valves of hard gun-metal composition were introduced, which have since become universally adopted. A broad flat surface was first employed, with the idea that in working at high pressure the beat of the valve on the surface would require a separate face. The effect, however, of this was that the water passing between the broad flat areas scarred the metal, and in addition, the annular surface under the accumulator required a greater pressure on the plunger to lift the valve. The consequence was that the metal of the pump became strained and caused a loud report, which was due to the expansion and subsequent contraction of the metal. This was at first regarded as a beat of the valve, but subsequently it was observed that during a short interval the pressure on the pump-barrel ran up very much above the accumulator pressure, owing to the latter acting on the large annular surface of the valve. On one occasion when the engine was worked rapidly, the violence of the shock burst the pump-barrel, although it was exceptionally strong. This concussive action was made the subject of a communication to the Institution of Civil Engineers by Lord Armstrong as far back as 1853. He pointed out that, in all cases in which pumps are to be worked rapidly against a heavy pressure, it is important that the area of the valve

COMPOUND STEAM PUMPING ENGINE.



Scale.

Ins 10 15 Feet

which is acted upon from beneath should bear a large proportion to the area that is pressed upon from above. As a general rule, concussion arises on the fall of the valve, and is caused by the valve having an excessive rise which involves too much time for closing, so that there is a slight interval on the turn of the stroke when the valve is open, and is then suddenly forced down by the pressure of the return stroke. Another cause of concussion is the momentum imparted to the delivery water by the previous stroke of the pump producing an overrunning of the column in the delivery-pipe. To provide against an excessive rise of the valve it is usual to make them of large dimensions, and with two or more bearing-faces, having a small rise for each; at the same time a large area is provided for the passage of the water.

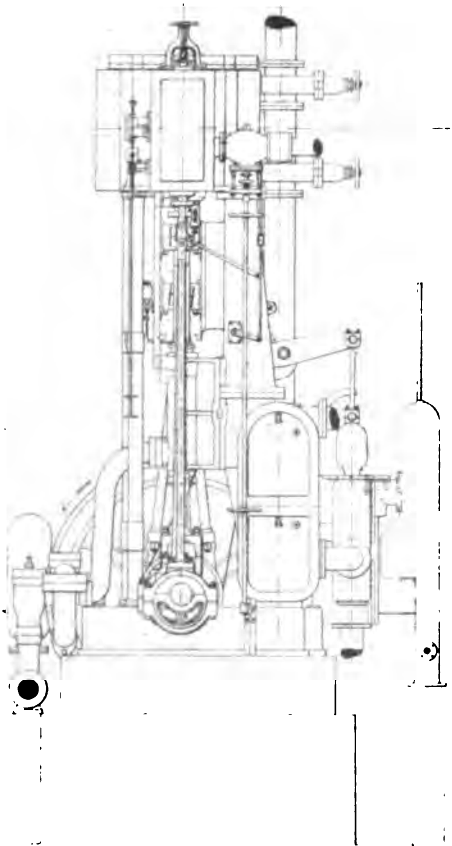
Plate 18 shows an Elswick high-pressure, compound, condensing steam pumping-engine. It is on the double tandem type, having two high- and two low-pressure steam cylinders arranged one behind the other. The pressure pumps are in the rear of the low-pressure cylinders, and are worked direct by a prolongation of the piston-rod, which is common to both cylinders. There is a cylindrical surface-condenser with air-pump placed vertically, and worked directly off one of the crank-pins. The circulating pump is similarly placed and is worked off the other crank-pin. The engine is arranged to work without the condenser when required, provision being made for exhausting into the air. The high-pressure cylinder has double slides, the point of cut-off of the expansion slide being varied from the outside of the steam chest. The pressure pumps have mitre valves. The rams and pistons are single-acting in suction, and double-acting in delivery. The engine is self-contained, and the bed plate takes all strains, only needing to be bolted down to a simple masonry foundation. A governor for preventing racing is provided, and also a spring-loaded plunger on the delivery main, to absorb shocks of the water column.

The Hydraulic Engineering Company of Chester erected

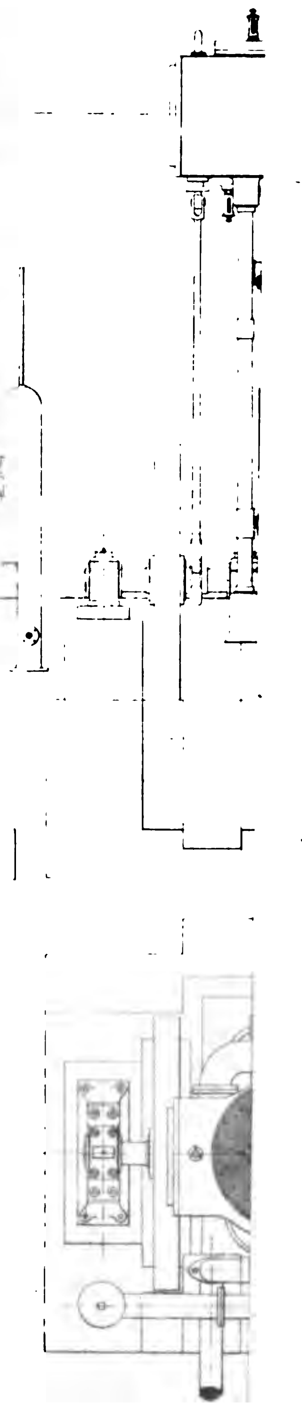
(some few years ago) a three-throw compound-engine at the London Hydraulic Power Company's central pumping station. The centre cylinder is high pressure, 19 inches diameter, 2-feet stroke. The two outer cylinders are low pressure, 25 inches diameter. The pump plungers are 5 inches diameter, and the quantity of water delivered into the accumulators under trial was 296 gallons per minute. The work stipulated for was 140,000 gallons in ten hours, the actual quantity pumped being 156,480 gallons, or an average of 260 gallons per minute. The engines are fitted with surface condensers, and with air- and circulating-pumps. They will stop and start in any position, make a single revolution, and stop again. The indicated HP gave a maximum of 205 HP, and 84 per cent. of efficiency in water pumped. The consumption of small coal in Lancashire boilers, with Vicars' stokers, was 2·4 lbs. per indicated HP, and the weight of steam 20·7 lbs. per indicated HP. The main valves are made on the balanced type of lift valve, with a waterway the full area of the pipe. The balancing is effected by a small controlling valve 1½ inches in diameter, inserted inside the large valve, by which only the small valve and the weight of the large valve have to be raised. A man can, with a 12-inch lever, lift and lower a 6-inch valve, under a pressure of 700 lbs., which is equivalent to a load of 8·8 tons pressing the valve on its seat.

At the Wapping Station of the London Hydraulic Power Company is one of Ellington's three-throw triple-expansion steam pumping-engines, the general arrangement of which is shown by Plate 19. It is of the triple-expansion type, with cylinders 15 inches, 22 inches, and 36 inches diameter, and with a stroke of 2 feet. The cranks are set at angles of 120 degrees. Each cylinder drives a single-acting pump 5 inches diameter direct from the piston-rod crosshead. The working steam pressure is 150 lbs. per square inch and the hydraulic pressure is 800 lbs. per square inch. Each set is capable of delivering 300 gallons of water per minute at a piston speed

ENGINES AT THE LONDON HYDRAULIC POWER C(



END ELEVATION



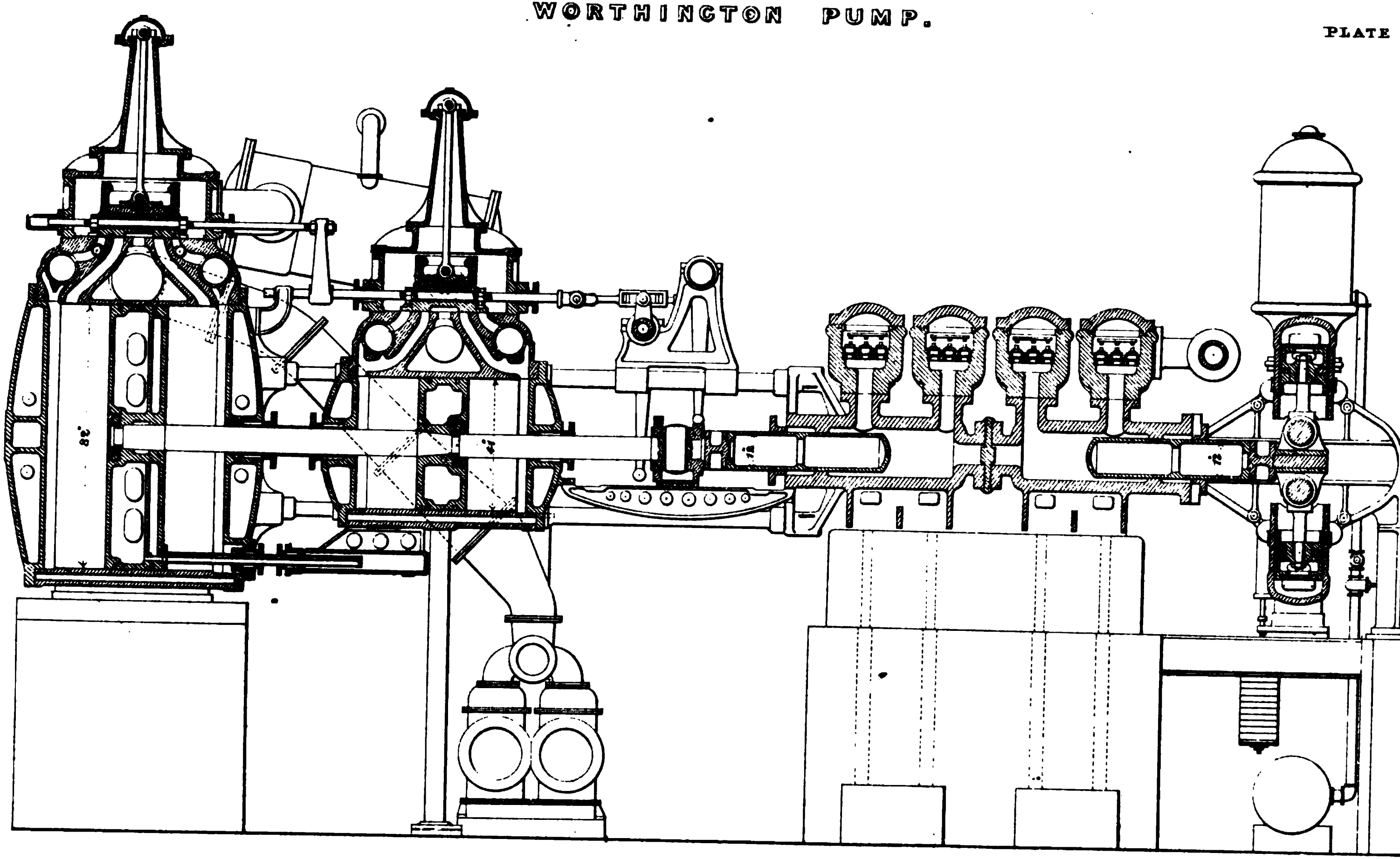
of 250 feet per minute. The engines are provided with surface condensers, forming a part of the engine frame, and with air-, circulating-, and feed-pumps driven from the crosshead of the intermediate cylinder through links and rocking shaft. The high-pressure cylinder is provided with expansion slides, with external means of regulating the same whilst running, the range of cut-off being indicated on an engraved brass plate. All the cylinders are steam jacketed, and are clothed with non-conducting composition, and covered with planished sheet steel. The engines are fitted with a high-speed governor actuating a throttle valve.

In ordinary forms of engines for pumping high-pressure water, the piston speed is about 300 feet per minute, although the engines can be run at 400 feet, or even more; if occasion requires.

Where the pumping-engines are of the crank and flywheel type, the pump-pistons move at a variable speed according to the angularity of the connecting-rod, and the quantity of water that is delivered varies at each instant, from zero at the ends of the stroke, to a maximum about half stroke, when the pistons are moving with the same velocity as the crank-pin. This variable delivery produces a change of velocity in the rising main, and where the engine is pumping through a long main, or one which contains a large body of water, very severe pressures are caused in the pump by the changes of velocity and the inertia of the water. This variation of pressure is compensated for by air-vessels, otherwise the pressures set up in the pump are sufficiently great to fracture the rising main or pump-work. In cases where (through the heavy pressures in the air-vessels) difficulty exists in retaining the air, advantage is experienced in adopting a pump in which the delivery of water is constant, and is not controlled by a crank and flywheel. The "Worthington" form of pump is attracting much attention now, as it fulfils the conditions referred to, the delivery being uniform at all parts of the stroke. There are two pumps, each double acting, the flow

from one dovetailing into the flow from the other. The steam cylinders are directly in line with the pumps, and there are no cranks or flywheels. This system has been adopted in pumping oil in America, where, owing to the great length of the mains and their smallness, the head on the pumps is all due to friction. When oil was forced with pumps whose motions were controlled with cranks, such excessive pressures were set up, owing to the change of velocity in the mains, and consequent increase of frictional head, that the pipes were continually bursting. Plate 20 shows a Worthington engine of about 800 HP. The low-pressure cylinders are 82 inches, the high-pressure cylinders are 41 inches, and the pump plungers are 12 inches in diameter. The pressure they force against is 1,500 lbs. per square inch, which is equivalent to a dead pressure of 151 tons, nevertheless the engine works perfectly and noiselessly. The steam pressure is 100 lbs. per square inch, worked at a high rate of expansion. The combination of an uniform pressure of steam in the engines with a high rate of expansion has been a matter of much comment, and is explained by Messrs. Simpson (the makers) in the following way:—With compound pumps, as formerly constructed, steam was admitted to the small high-pressure cylinder at its full pressure for the whole length of the stroke, and was then exhausted into the large low-pressure cylinder to do duty on the return stroke at a lower pressure, but on a very much larger area of piston. By this means, with an initial pressure of about 80 lbs., a mean effective pressure was obtained for the two cylinders working in tandem, that would be equal to about 40 lbs. on the large cylinder with pumps of the usual proportions. With the high-duty engine, the object is to get a result equal to any degrees of expansion up to the possible economic limit, and at the same time to preserve all the approved features of the pump as originally constructed. The apparatus to accomplish this consists of two opposed small oscillating cylinders connected to an extension of the plunger-rod of each set of cylinders, as shown in the cut at the water

WORTHINGTON PUMP.



Thos Kell & Son, Lith.

end. These cylinders and their connections are filled with water (or other liquid). Compressed air from an accumulator or storage reservoir is admitted to the surface of the water (or other liquid) that goes into these small cylinders, at a pressure suitable to the duty to be accomplished, for the purpose of maintaining a constant load at a practically constant pressure on their pistons through the medium of the interposed liquid. These pistons act in opposition to the engine up to half the stroke, during which time the steam in the high-pressure cylinder may be at its initial pressure, then the point of cut-off may be established, and, as the steam-pressure diminishes, the force that is stored by the compression is given off and is restored to the sources from which it came, securing a practically constant exertion on the piston-rods and water-plungers throughout their whole stroke. The two small cylinders for the reciprocation of power are placed directly opposite to, and balance, each other, thus relieving their crosshead from any side strain on the slides.

For slide-valve engines of this description the cut-off can be fixed at a suitable fraction of the stroke of the small cylinder; or, in other words, the steam may be taken at a high pressure until it only partly fills the small cylinder, then it is expanded to the end of the stroke and admitted to the large cylinder to be further expanded. Where the most economic results are desired, the low-pressure as well as the high-pressure cylinders on the engine are provided with cut-off valves. These consist of semi-rotating plug-valves placed in the admission ports of the cylinders, and are worked by means of the direct connections shown in the Plate. The point of cut-off can be fixed by experiment for both cylinders, and need never be altered while the duty remains the same. One of these engines has been carefully experimented on by Mr. Mair-Rumley (of Messrs. Simpson & Co.), and he found that as high a degree of economy was obtained as with any type of crank and fly-wheel engine, whilst a perfectly uniform stream of water was delivered.

A Worthington hydraulic compound pumping-engine has

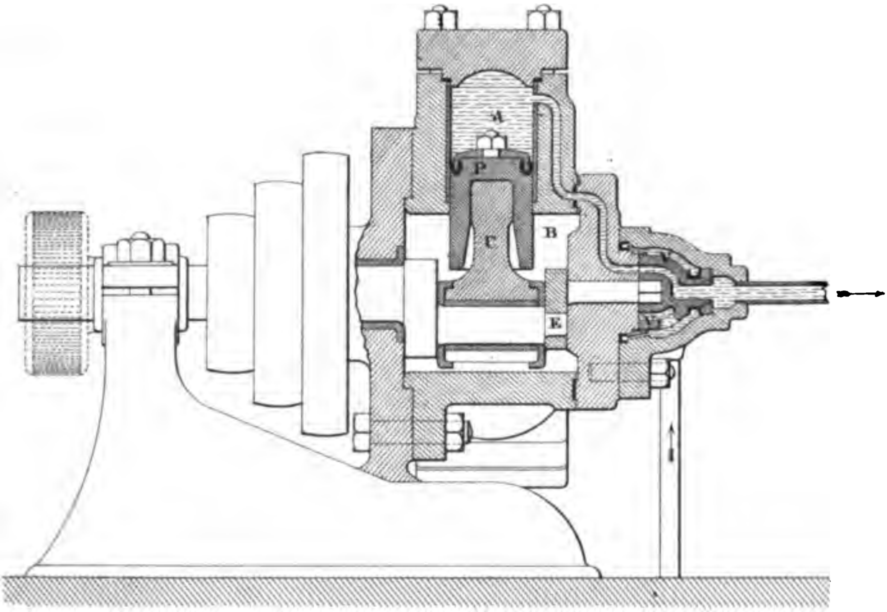
been recently erected by Messrs. Simpson & Company at the Grimsby Docks to replace a fly-wheel hydraulic pumping-engine. The steam-pressure is 60 lbs. to the inch. The high-pressure cylinders are $20\frac{3}{4}$ inches in diameter and the low-pressure cylinders are 32 inches in diameter, stroke 3 feet 6 inches. The diameter of the plungers is $7\frac{1}{8}$ inches. The piston-rod, $3\frac{1}{2}$ inches diameter, is connected with the front plungers by a strong cast-iron crosshead, which connects again with another crosshead attached to the back plunger by means of steel rods working and guided outside the main pump body. The back and front crossheads both work on guide bars.

The cylinders are attached to the main pumps by cast-iron frames which carry the valve gear. Both cylinders are thoroughly jacketed.

The steam exhausts into a surface condenser, the vacuum in which is maintained by an independent air and circulating-pump. The surface condenser is 12 feet long by 4 feet 2 inches internal diameter, and consists of 354 tubes, giving a cooling surface of 1,500 square feet. These are secured by means of packed screwed ferrules between gun-metal plates. The injection water is made to pass through the tubes and must circulate by means of baffle plates up and down the whole length. The steam is condensed outside the tubes, and the exhaust from the air- and circulating-pumps is also led into this space. The condensed steam on leaving the condenser is led into a hot well, and is pumped together with the jacket water back into the boilers by means of an independent feed-pump. The air-, circulating-, and feed-pumps are brass fitted throughout. The main engine-pumps are of massive design, and work without noise when going at their full speed. To the pump body (which is $1\frac{1}{2}$ inches thick with flanges $2\frac{3}{8}$ inches thick) are connected the suction and delivery valves, of which there are eight to each pump. The pumps are of the outside packed plunger type and the valves are of gun-metal.

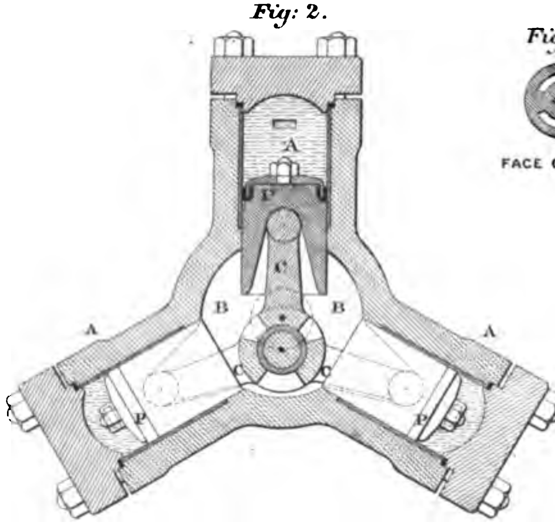
BROTHERHOOD'S THREE CYLINDER HYDRAULIC ENGINE.

Fig: 1.



LONGITUDINAL SECTION.

Fig: 2.

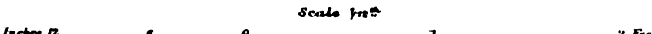


TRANSVERSE SECTION.

Fig: 3.

FACE OF VALVE.

Scale



Thos Kell & Son, Lith

The action of the pump is as follows:—The air- and circulating-pumps are first started, and a vacuum is formed in the condenser with their own exhaust. Steam is then turned into the main engines and the supply is entirely controlled from the accumulator in the ordinary way. The engine but rarely quite stops, and if it does, it starts again automatically; one of the special points in these engines being that there is no dead point. This engine is capable of pumping 600 gallons per minute against a pressure of from 700 to 720 lbs. per square inch.

THREE-CYLINDER ENGINES.

For some time after the introduction of hydraulic machinery for purposes to which a reciprocating motion was required, great difficulty was found in adapting it to obtain rotary motion, and many forms of engines have been invented for that purpose. On the Continent Haag's engine has been largely employed; in this the oscillation of a cylinder on its axis alternately opens and closes the ends of the axis to admit and exhaust the water. Ramsbottom devised an engine with three cylinders oscillating on a cast-iron pipe, which was divided by a longitudinal diaphragm into two sections, one of which supplied the water to the cylinders, and the other exhausted the water from the cylinders through ports.

BROTHERHOOD ENGINE.

The Brotherhood three-cylinder engine is an excellent appliance for producing rotary motion by water-pressure. A description of this was given to the Institution of Mechanical Engineers, and is shown by Plate 21, Figs. 1, 2, and 3. Three cylinders A (made in one casting) are always open at their inner ends, and are attached to a central chamber B. They

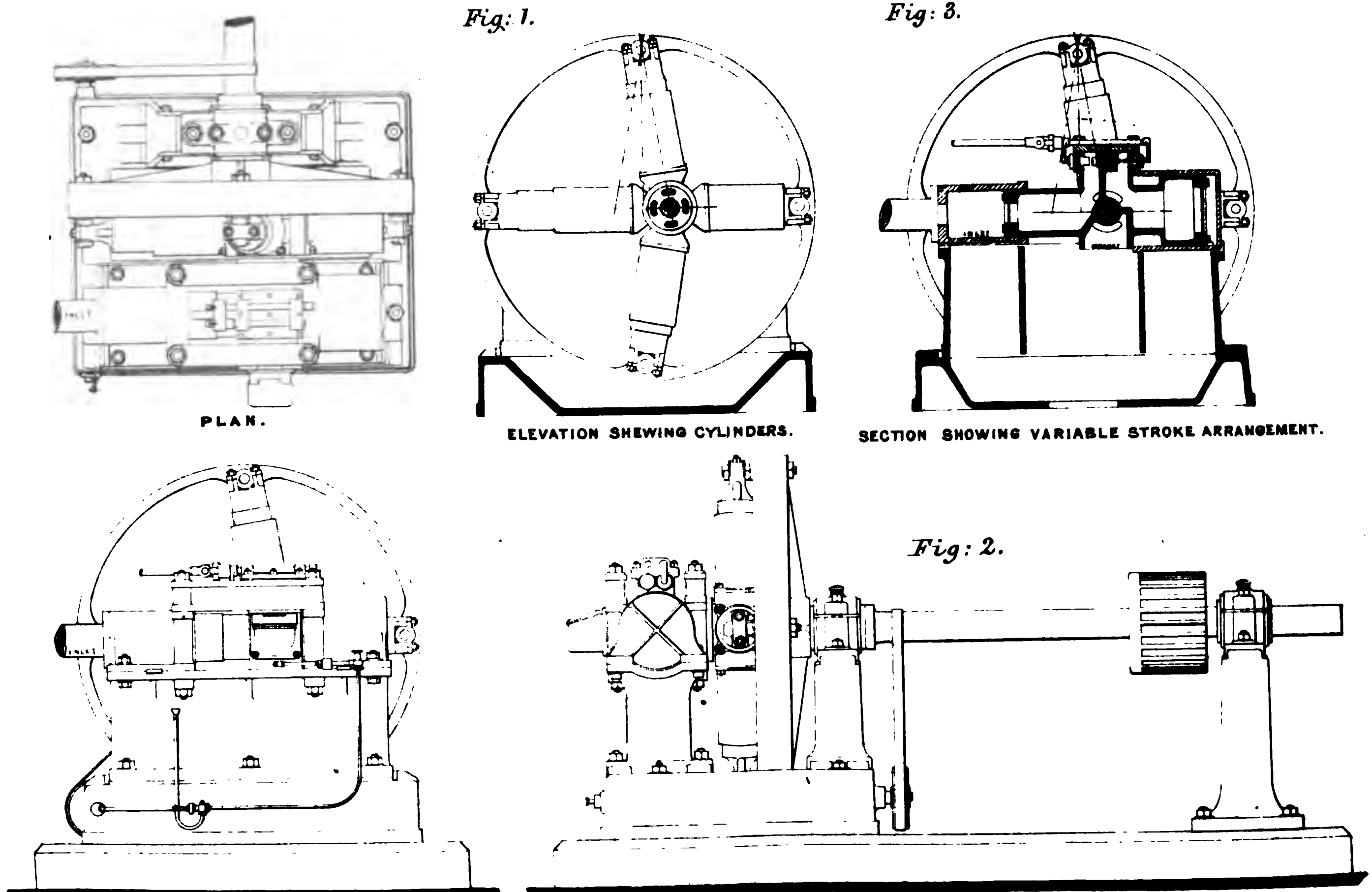
contain three pistons P, which transmit motion to the crank-pin through the struts C. The water is admitted and exhausted by means of the circular disc valve V, with a lignum vitæ seating. The valve is rotated by the eccentric pin E. A face view of this valve is shown in Fig. 3. It has segmental ports which, in rotating, pass over apertures in the valve seating. There being no dead centre, the engine will start in any position of the crank-pin, and a perfectly uniform motion of the shaft is obtained without a flywheel. The pressure is always on the outer end of the piston, so that the struts C′ are in compression, and take up their own wear. This engine is well adapted for transmitting pressure to appliances which are worked intermittently, as, owing to the great speed at which it can be run, it will not only save the loss from friction (where gearing is employed), but will also reduce the friction in the machine itself, by enabling the gearing for increasing speed to be dispensed with.

RIGG'S HYDRAULIC ENGINE.

This engine is an inversion of the usual reciprocating type, whereby the crank remains stationary, and the engine proper revolves around it, and as each of its three or four cylinders in turn presents its port opposite the inlet or outlet, water is admitted or discharged. Every one of the three or four cylinders has its own proper dead centre, but as one or more are always driving, a sufficient tangential effort is always present for causing this engine to start, or stop, just as others do when provided with more than one cylinder.

The cylinders revolve upon a crank-pin which does not turn round. By altering its radius the stroke of the pistons can be changed, and this movement may extend to reversing the direction of movement altogether, by sliding the crank-pin right across its zero position (that is, where cylinders and pistons revolve upon the same centre). Thus the stroke can

RIGG'S HYDRAULIC ENGINE.



PLAN.

Fig: 1.

ELEVATION SHEWING CYLINDERS.

Fig: 3.

SECTION SHOWING VARIABLE STROKE ARRANGEMENT.

FRONT ELEVATION.

Fig: 2.

SIDE ELEVATION.

West, Newman Photo.

be regulated in accordance with the demand for power, and no more water is used than suffices for the work done. Governing this engine can be accomplished by any ordinary form of governor, set so as to alter the stroke, and a constant speed is thus maintained, however changeable may be the work done. This effects economy, as the consumption of water corresponds with the work done.

Plate 22, Figures 1, 2, 3, illustrate one of these revolving engines, which was employed for winding waggons up a steep incline, and was worked by a pressure of 200 lbs. per square inch. This engine has four cylinders, each 6½ inches diameter, with a maximum stroke of 9 inches in either direction of motion, and this direction, along with the length of stroke, is determined by hand.

In Figure 1, the valve-face is removed, which permits the four cylinders to be seen in elevation. Each is a separate gun-metal casting, and all revolve around the crank-pin as a common centre; the maximum eccentricity of which is 4½ inches, corresponding with a piston stroke of 9 inches. This crank-pin (or stud, carrying the cylinders) can be placed on either side of the centre, and its distance determines the length of stroke, shortening as the centre is approached, and lengthening according to the positions shown by the dotted lines in this Figure. At the middle, or zero position, when cylinders and pistons revolve around a common centre, there is no stroke whatever, no water used, and no power given out.

A pressure of 200 lbs. per square inch, acting on the area of a piston 6½ inches in diameter represents a total of something like 3 tons, an amount obviously far beyond any direct manual power to control, consequently it becomes necessary to provide another engine, acting as a "relay," and the valves of this auxiliary engine can easily be worked by hand. This second engine is shown in side elevation by Figure 2, and in section by Figure 3, and it forms a part of the slide carrying the stud or crank-pin.

Pressure entering on the inlet side acts permanently against a ram, which also serves to conduct the inlet to ports on a valve-face, indicated by dotted lines. Opposed to this ram is another of double its area, and whenever pressure is admitted behind this larger ram, it drives back the smaller one, and alters the stroke of the revolving engine; or, when a port from the larger ram is opened to exhaust, it is forced backwards, owing to the constant pressure behind the smaller ram.

Valves for controlling these movements are carried by the slide itself. The one for admitting pressure behind the larger ram is shown on the section, and the other for exhausting stands exactly behind it, and is worked in the opposite way. The general effect of these arrangements is similar to those of a steering gear, enabling the operator to move the central stud and hold it in any position, with the greatest ease. By shortening the stroke the driving power may be brought so low that a descending load can be used to wind the engine backwards. It thus becomes a pump raising water to its original level, and acts as a powerful brake.

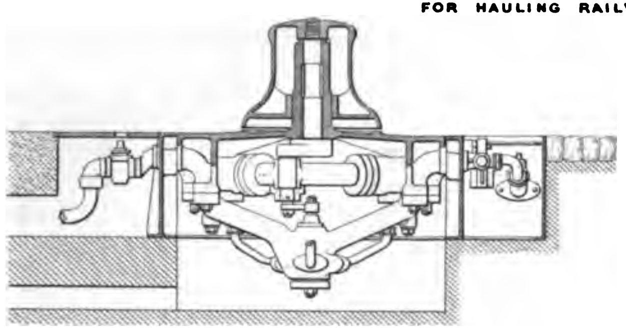
When a governor is applied to the auxiliary engine, it merely moves a pair of balanced valves, and so determines the stroke and speed of the engine, proportioning the quantity of water expended in accordance with the demand for power, and maintaining a uniform speed of rotation.

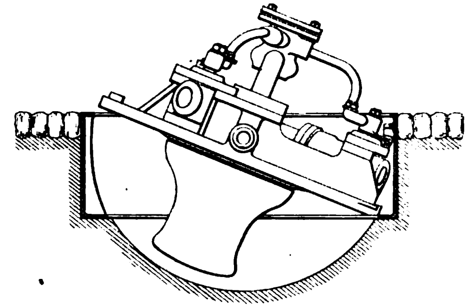
HYDRAULIC CAPSTANS.

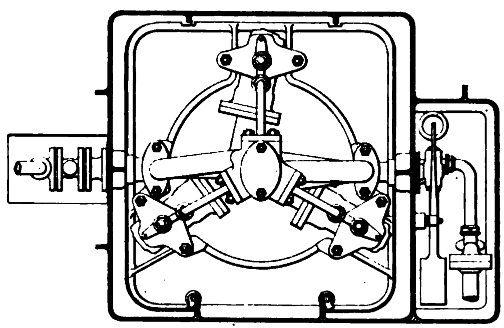
The production of a simple hydraulic rotary engine led to its application to capstans, several forms of which have been introduced. One of the most recent and compact is that made at Elswick, which may be termed the Turnover Hydraulic Capstan, as shown by Plate 23. A bed-plate is hinged upon two trunnions, one admitting the pressure, and the other being used for the outflow of the exhaust water, after it has passed through the working valve or valves. To the

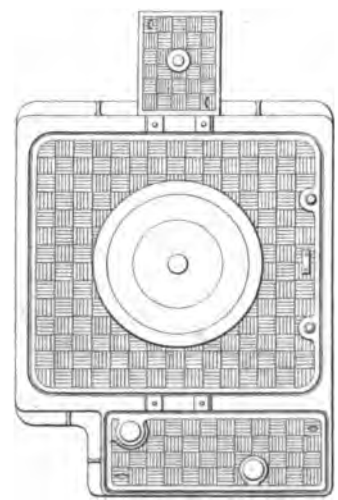
TURNOVER HYDRAULIC CAPSTAN.

FOR HAULING RAILWAY WAGONS.









Scale.

Inches 12 9 6 3 0 1 2 3 4 5 Feet

Thoˢ Kell & Son, Lith.

bed-plate is cast a pillar, through which the crank shaft is guided, and to the other end of which the capstan head is fixed. To the single crank, on which the three rams act, is attached a cross-rod communicating motion to a rotary valve, from which branch pipes convey the water to and from each cylinder. The trunnions of the bed-plate are carried on bearings attached to a cast-iron casing, which forms a framework for the capstan, and on which also is carried the working valve for regulating the starting and stopping of the capstan. This working valve is usually a mitred valve, to which a counter-weight and lever are attached, in such a manner that the counter-weight, when free, keeps the valve closed. To start the engines, the lever is pressed with the foot, thus raising the weight which keeps the valves closed. When the foot is removed the valve is closed, and the action of the capstan is stopped. The capstan is so balanced on the trunnions that it can be easily turned over by one man. The advantages of this arrangement chiefly consist in the facilities that are afforded for examining and oiling the parts. The capstan can be worked in any position, so that its action can be readily seen and adjusted. The usual power given to working capstans is equal to a hauling power of about one ton on the rope, but smaller capstans than these are used where only one or two waggons are required to be moved at a time. The speed of the capstan can be varied from 2 or 3 revolutions per minute to upwards of 100 revolutions.

The late Mr. B. Walker devised a double-acting capstan engine with two cranks set at right angles to each other. The arrangement of cylinders consists of two pairs, each pair being composed of a small and large cylinder, having a ram common to both, but of different diameters. The smaller rams are always in communication with the accumulator, whilst to the larger rams the water-pressure is admitted alternately by means of a slide valve, to which motion is given by the ram crossheads.

The introduction of hydraulic capstans into railway goods

yards and other similar places, has proved of great advantage in expediting the operations of shifting trucks, making-up trains, and the like.

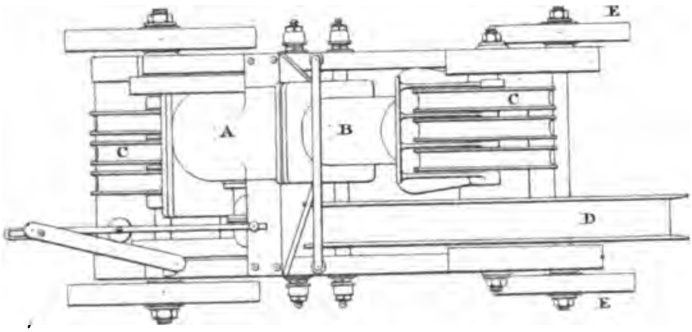
HYDRAULIC TRAVERSERS.

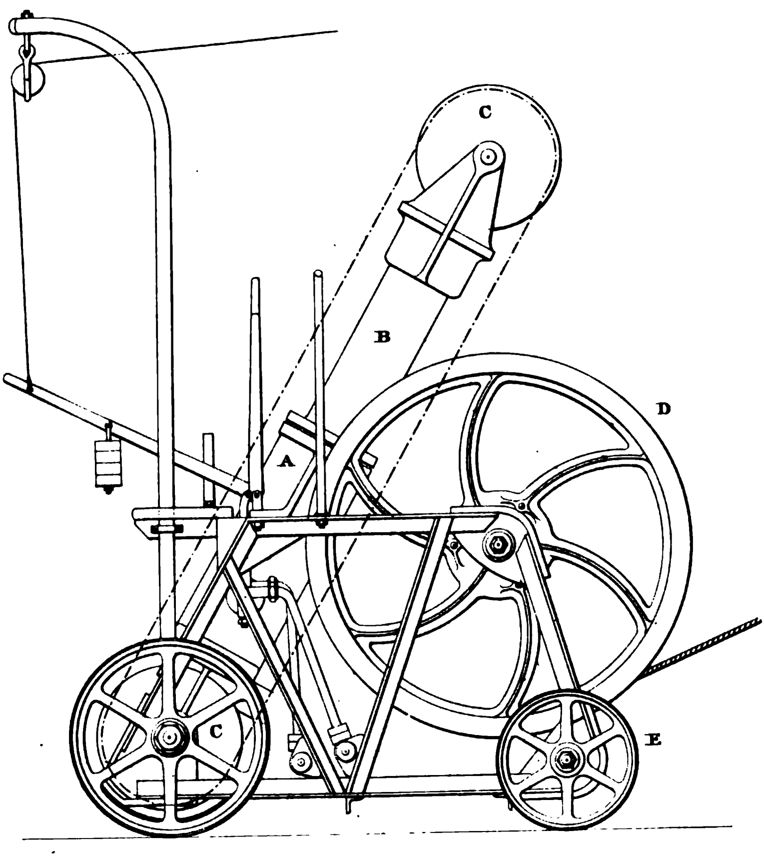
The transference of railway trucks or carriages from one line of rails to another is rapidly effected by traversers worked by hydraulic power. The expedition in making up trains, both goods and passenger, that results, has led to their extensive use. The construction simply consists in detaching a length of the line, sufficient for the carriage or truck to stand on, and by suitable framing beneath to support it on rollers resting on rails. These rails are laid between the two lines to be served by the traverser, and they enable the frame, with the carriage or truck on it, to be rolled from one line to the other. This can be done by placing a hydraulic cylinder and ram with multiplying sheaves in a pit adjoining, and by connecting the chain or cable to the traverser, a short stroke of the ram produces a long run of the traverser. At the new harbour at Frankfort-on-Main an installation of hydraulic power has been carried out by Mr. W. H. Lindley, the engineer to the Magistracy of that town. The author had to inspect this installation in 1888. Traversers are used with a travel of 44 metres between centres of rails, and this long run involves the employment of three-cylinder engines, the power being conveyed by cables passing over a series of sheaves arranged in straight lines, by which no undue wear and tear of the cables arise. A trial of one of these traversers gave 220 seconds as the time occupied in the several operations of bringing the traverser from one line to the other, hauling a truck on to it, transferring it to the other line (44 metres away), and hauling the truck off. A trial was made by running the traverser a longer distance than between these two lines (the range of travel extending to more than two

PLATE. 24.

MOVEABLE JIGGER HOIST,

TO LIFT 15 CWT.





Scale 3/8 Inch = 1 Foot.

Inches 12 9 6 3 0 1 2 3 4 5 Feet.

Thos. Kell & Son, Lith. 4 King St. Covent Garden

lines of rails). A waggon with a load of 15,500 kilogrammes was put on the traverser, which was run backwards and forwards through a total of 59 metres. The engines made 100 revolutions and used 310 kilogrammes of water.

MOVABLE JIGGER HOIST.

A Movable Jigger Hoist is shown by Plate 24. This machine consists of a hydraulic cylinder A, with a ram B, and multiplying sheaves CC. The lifting rope or chain passes over the large drum D, and the chain for communicating the power from the cylinder passes over a smaller one which is attached to it. The lifting slide valve is fixed to one side of the cylinder, and is worked by a man standing on a platform above the valve. Valve gear can be fitted to the machine (as shown in the figure) by which the jigger can be worked by a man standing on a ship's deck, and looking directly into the hold. The machine itself remains on the quay, thus dispensing with one man. It is mounted on a wrought-iron frame, carried on four wheels E, so as to allow of its being moved from place to place. The water is conveyed to the machine, from the main, through jointed pipes, which allow a considerable amount of travel of the jiggers without alteration of the pipe connections. The pressure and exhaust connections on the jiggers are shown, with caps for protecting the joints when the machine is not in use. These jiggers are of varying powers, according to the purpose to which they are to be applied, whether for lifting sacks of corn, or light jute bales. They work with great rapidity, making from four to five lifts per minute from the hold of a vessel.

HYDRAULIC WAGGON DROP.

In the arrangements for charging blast furnaces, a waggon drop is generally employed for lowering the charges into the furnace, the downward movement being controlled by a brake applied to the shaft on which are fixed the sheaves for the chains or wire ropes. Mr. Thomas Wrightson has successfully applied water as the controlling agent of the brake, and he described this arrangement at a meeting of the Iron and Steel Institute. Fig. 28 shows the means by which water in this case is utilised as an hydraulic brake. A cylinder A (10 or 12 inches diameter) has a stroke the same as the rise or fall of the cage, which is suspended from the piston-rod D, at the other end of it being the piston C, working in the cylinder. At the top of the cylinder is a small supply tank E, fitted with a self-acting ball-cock, to keep the same always supplied from the nearest water main. A small adjustable hole F in the cover communicates with the inside of the cylinder, to ensure that it is always full of water, and another small hole G in the piston allows any air which may accumulate under the piston to pass to the upper part of the cylinder, where it escapes into the tank by the hole F.

A pipe H connects the top with the bottom of the cylinder, through an ordinary water-cock J, which is controlled by a weight-bar and lever. A catch lever is placed alongside the valve lever, and serves to lock the cage as it comes to the top of its stroke. This holds the cage while the waggon runs on. When the cage with the waggon on is required to descend, the catch rod is liberated, and then the valve handle is lifted. By the opening of this valve J the water passes from the bottom to the top of the piston, thus controlling the descent of the cage with the greatest nicety to any speed the attendant may choose. When the cage is at the bottom, a self-acting stop is removed by the

action of the cage touching the ground, which allows the waggon to run off at the lower level. The cage being then lighter than the counterweights, is drawn up again, the water in the cylinder, during the ascent, returning from the top to the bottom of the piston. When the cage arrives at the top of its stroke, it locks itself, and is then ready for another waggon to be run on.

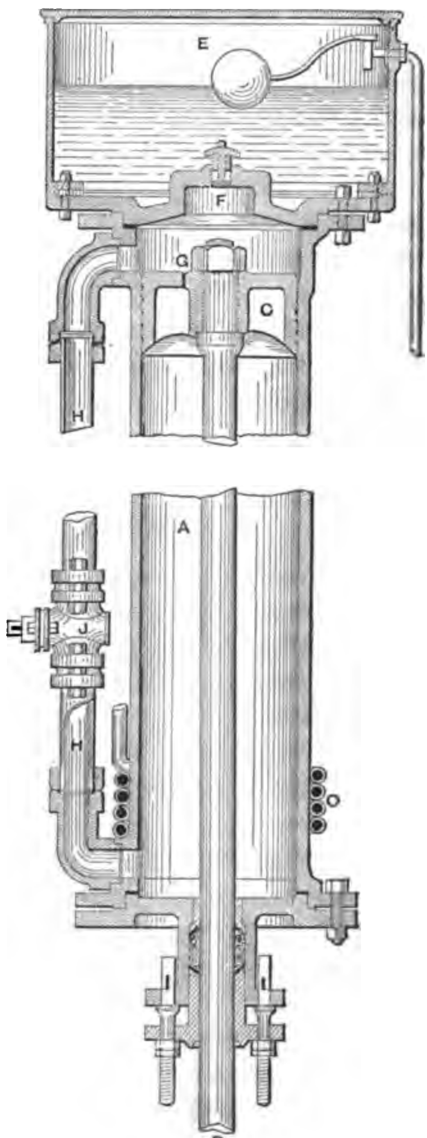


Fig. 28.

The bulk of the water passes and re-passes through the cock J, but on account of the area of the piston being less on the lower side than the upper (by the area of the piston-rod on the lower side), the water at the top, displaced as the piston rises, cannot find room at the lower side of the piston, and will, therefore, find relief by a portion (equivalent to the cubical contents of the piston-rod) passing through the small hole in the cylinder cover into the supply tank. In the same way when the piston again descends, there would be an equal deficiency in the water passing from

the bottom to the top side of the piston; this is compensated for by the same amount of water re-passing through the hole in the cover. By this means the cylinder is always kept full of water, which is essential to the successful working of the apparatus. It will be observed that the same water is used over and over again, and that the ball valve in the tank is merely to supply any loss from evaporation or leakage. The small pipe O, encircling the cylinder, is for the admission of steam in frosty weather to prevent the freezing of the water. This comes from the nearest steam or exhaust pipe, and after coiling a few times round the lower part of the cylinder, passes up to the top tank alongside of the connecting pipe.

HYDRAULIC JACK.

The hydraulic jack is an appliance forming a combination of the hydraulic press and pump. It is illustrated by Figs. 29 and 30, by permission of the patentees, Tangyes, Limited.

The ordinary jack is shown by Fig. 29. A ram A, resting by a foot-plate on the ground, carries on the top a cylinder C, to which is attached the combined press and pump in the chamber B. This chamber serves as a reservoir, and is filled with water (or a mixture of glycerine and water in cold climates) when the jack is to be used. The water is run into the reservoir by a charging hole at the side. A lever attached to a spindle at D enables the short crank E of the force-pump of the press to be raised and lowered. Water is drawn into the pump cylinder (through a suction valve) from the reservoir at the up-stroke, and is forced by the down-stroke on to the head of the fixed ram beneath, by which the cylinder and the load resting on the top of the press that is carried by it are raised. The head of the ram is fitted with leather packing at F, against which the water acts and makes a water-tight joint. The top of the jack is covered with an iron plate, screwed on

water-tight. When the jack is at work, a small screw in the side of the chamber B has to be slackened to allow air to pass in and out.

Fig. 29.

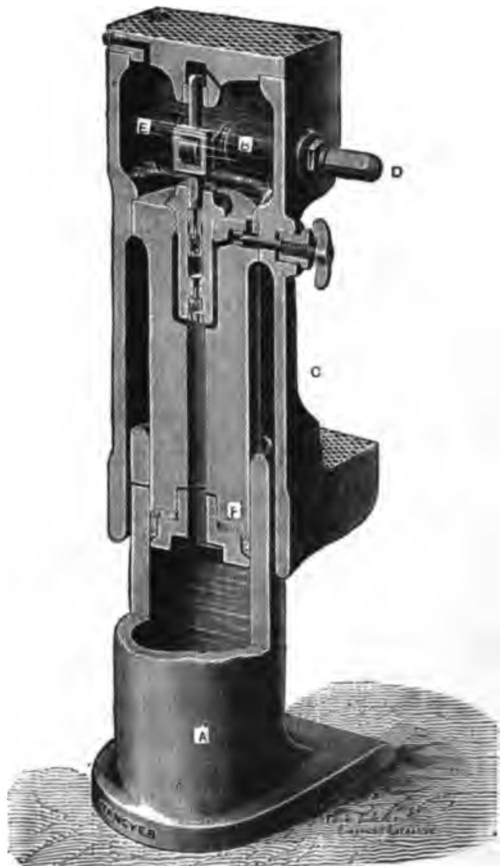


Fig. 30.

An enormous upward force is exerted, which is due to the leverage that is brought to bear on the plunger of the force-pump, acting on a small area, and thence to the larger area of

the top of the ram. The weight capable of being lifted can be calculated, therefore, by the following expression:—

$$W = \frac{A}{a} \times \frac{L}{l} \times P.$$

Where

W = weight to be raised.
A = area of ram.
a = area of pump.
L = length of hand lever.
l = length of pump crank.
P = pressure exerted on the handle in pounds.

From experiments it has been ascertained that the efficiency of a hydraulic jack is about 77 per cent.

In the new type jack, shown by Fig. 30, the position of the leather is altered to the bottom of the cylinder, as at F, by which the leather is kept moist so long as any fluid remains in the jack. This is an advantage in hot climates, where the leather is more liable, when the jack has been long out of use, to get dry and useless. One man can work a jack capable of raising loads up to 60 tons.

DUCKHAM'S WEIGHING MACHINE.

A simple, portable weighing machine has been devised by Mr. Duckham, which is useful for weighing materials in places where rough treatment may be expected, and machines with springs would be injured. The principle on which it is constructed is that of suspending the load to a rod, which is attached to a piston, working loosely in a cylinder filled with water. A gauge is connected by a small opening to the cylinder, so that the pressure exerted by the piston carrying the load is transmitted through the water to the gauge, and is recorded on a dial.

SHOP TOOLS.

The employment of hydraulic pressure to workshop tools dates as far back as Bramah's time, a hydraulic planing machine having been then erected at Woolwich, in which many of the operations of the tool were performed by water-pressure. About thirty-five years ago a direct-acting hydraulic slotting machine was at work for some years at Elswick. It had a stroke of about 4 feet, with a tumbling weight to reverse the action, and it was worked with an accumulator pressure of 700 lbs. per square inch. It was placed vertically upon girders supported by pillars 16 feet apart, thus enabling large pieces of machinery to be easily slotted.

The adoption of a pressure of 1,500 lbs. per square inch enables the sizes of shop tools to be reduced, and their portability and convenience thereby increased; but in case a lighter description of work has to be done, the pressure can be reduced by diminishing the weight in the accumulator.

The transmission of power by a pipe (instead of by belting or shafting) for actuating shop tools, is attended with advantages. Less wear and tear arise, and the power can be conveyed round bends, or to distant points, with great facility. The pipes being underground, the cost of the supports, columns, and bearings requisite for shafting is saved.

The object which has to be attained in manipulating wrought iron under a forging, bending, or other tool, is to dispose the fibres in the direction conforming to the purpose to which the iron is to be applied. Such disposition of the fibres or threads in uniformly continuous lines ensures the strength of the mass being preserved. The application of a blow results in a disturbance of this arrangement of the fibres (producing, as it were, eddies in the flow of the particles), and the power of resistance is necessarily lessened. In stamping metal, a squeeze, instead of a blow, results in the preservation

of the continuity of the particles. The shapes for the dies at the various stages of the work can be considered with reference to the natural tendency of the metal to flow in the direction of the pressure which is applied to it. The element of time in these operations has been proved to be an important factor in the changes of form which are produced in metals when being manipulated. The continuity in the fibres of the metal is better produced by a slow blow or squeeze than with a sharp blow.

Hydraulic rivetting was carried out at the Elswick Works as far back as the year 1851, and the machine is still working. It was originally a steam rivetter, but was converted into a hydraulic rivetter, by simply altering the piston and valves, and by applying a set of force-pumps, connected with an accumulator which could be loaded to various pressures to suit the strain required to be given upon the varying-sized rivets, the largest being 1 inch. The maximum accumulator pressure that is applied to this machine is 300 lbs. to the square inch, which cannot be exceeded, owing to the water-pressure being applied to the original steam cylinder.

When Mr. Ralph Hart Tweddell directed his attention to hydraulic rivetting, he first experimented with steam rivetters, and diagrams were taken to determine the best pressure to produce a good rivet. This was especially directed to rivets in the thicker plates (such as 1¼ inch) that came to be adopted a few years ago for large boilers, and other descriptions of plate-work, where 1⅜-inch rivets or so were employed. A hydraulic rivetting machine was then designed by Mr. Tweddell, which proved that only a small amount of friction occurred in the machine. The advantage of the momentum due to the descent of the accumulator, when water was passing from it into the cylinder of the rivetter, combined with the steady pressure or squeeze due to the load, was established.

TWEDDELL'S HYDRAULIC RIVETTER.

One of Mr. Tweddell's fixed hydraulic rivetters is shown by Figs. 31 to 38. A side elevation is given by Fig. 31. An end elevation by Fig. 32. Fig. 33 is a plan and Fig. 34 a longitu-

Fig. 31.

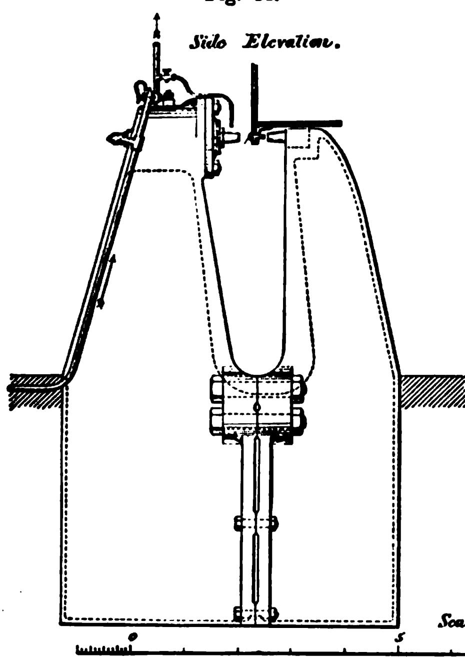
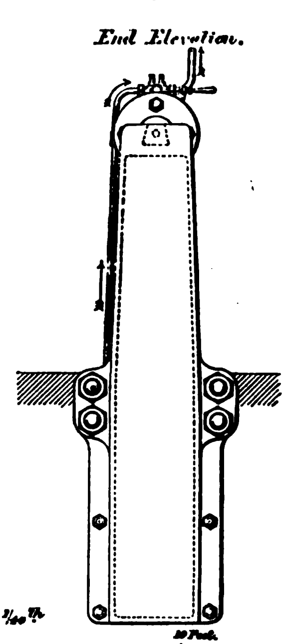


Fig. 32.



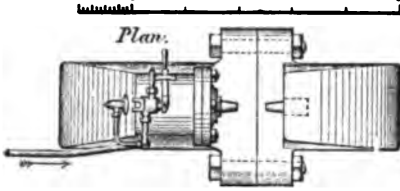


Fig. 33.

dinal section. Fig. 35 is a back elevation, and Fig. 36 is a front elevation. Fig. 37 is a sectional plan of the valve box. Fig. 38 is a longitudinal section of the ram. These illustrations are taken from the *Proceedings of the Institution of Mechanical Engineers.* The water from the accumulator is

admitted to, and exhausted from, the cylinder through the small aperture A, Figs. 34 and 38, by means of a simple hydraulic valve shown by Fig. 37. The water entering at

Fig. 34.

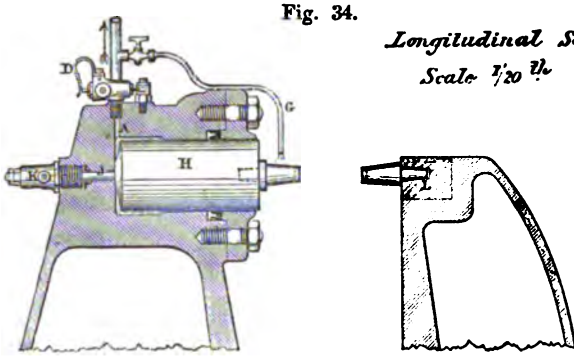


Fig. 35.

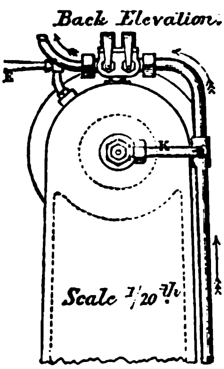


Fig. 37.

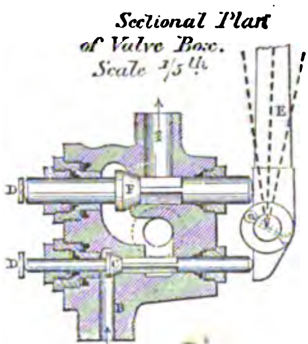
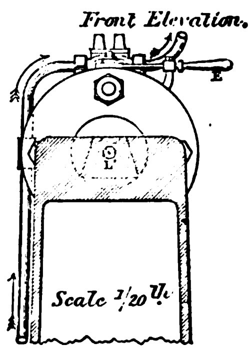


Fig. 36.



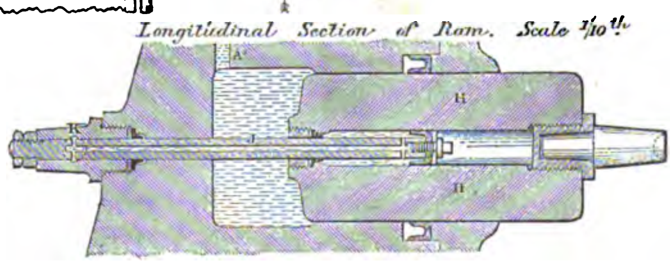


Fig. 38.

B tends to keep the inlet valve C shut, the spring D serving the same purpose until the accumulator pressure begins to act. On opening the valve C (by the hand lever E)

water is admitted to the cylinder and passes into it against the ram (8 inches diameter) until the rivet is closed. The exhaust valve F is kept shut by the pressure of water entering the cylinder, and at other times by the spring D, but by pulling the lever over the reverse way the exhaust valve is opened, by which the exhaust water escapes to the cistern, a small portion being allowed to flow through the pipe G (Fig. 34) on to the die, to cool it. The ram H is drawn back by means of the small drawback cylinder J (Fig. 38), which is arranged within the ram itself, and is in constant communication with the accumulator through the inlet K. The wedge-shaped fastening of the disc (as shown at L in Figs. 34 and 36) obviates any thickness of metal over the fixing pin ordinarily employed to keep the die in its place. This enables the rivetter to be used for rivetting flanged and angled iron work. These designs have been altered in points of detail of late years. A piston valve with leather packing is now used instead of the mitre valve, and owing to the pressure exerted by many of these machines being from 150 to 200 tons in closing the rivets, at the rate of four or five to the minute, the high-pressure water is economised by special arrangements, by which different powers are exerted. Cast steel is now largely used instead of cast iron for the main frames. Owing to the great thickness of the steel plates that are now employed, the rivetting machines now have additional rams by which the plates are first brought together by a closing tool, and are so held together while the rivet is being closed by the other ram.

The success which resulted from the use of water-power when applied to the fixed rivetters, led Mr. Tweddell to design a portable rivetter, which was able to be taken to the work, instead of the work having to be brought to the rivetter.

Figs. 39 and 40 show a sectional elevation and end elevation of one of the portable hydraulic rivetting or punching machines. In the cylinder A is a plunger or ram B, with two jaws CC, to which is attached a crosshead or horn D, fur-

nished at one of its ends with the cupping die E. The plunger B being forced forward by water admitted through a valve by the gearing F, the crosshead advances until it meets the resistance of one end of the other crosshead G at a point H, which is shaped to receive J, and at the other it comes in contact with, and closes, the rivet, or punches or shears the plate, according to the purpose it is used for. At the same time the outside crosshead (or one farthest from the cylinder) is held up against the crosshead D by two tension rods KK

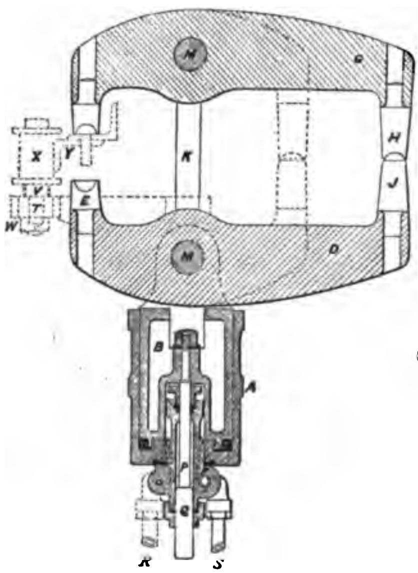


Fig. 39.

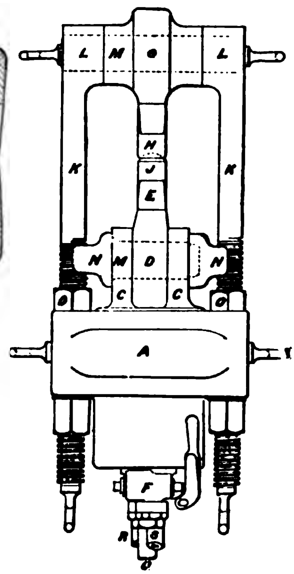


Fig. 40.

attached to the crosshead G at LL, and to lugs cast on the cylinder, the rods receiving the thrust. The horns or crossheads are supported by the through pins MM, whilst the horn which is attached to the plunger B is steadied by the guide N. The nuts OO regulate the distance from the face of the cylinder A to the centre line of the crosshead G. The ram B is always subject to a drawback action owing to the self-acting cylinder P having the accumulator pressure constantly exerted upon the shoulder Q. This power comes into action

as soon as the water is exhausted through the valve F. The water-pressure is admitted to the cylinder P by the inlet pipe R, and is exhausted by the pipe S, both being worked by a handle.

The dotted lines show the arrangement for keeping the machine up to its work. A frame T is fixed to the outer horn D, and in this is a pin V attached to the frame by a nut W, and having on it a roller X, which has a free rotary motion. The roller is covered with some flexible material, and serves to keep the machine in its right place, and up to the work Y.

A form of portable hydraulic rivetter is made which can be

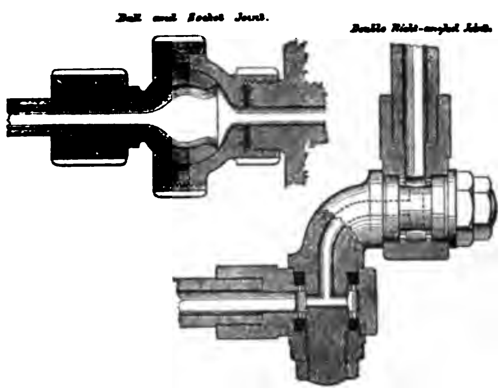


Fig. 41.

fixed to a bracket temporarily at any part of a yard where rivetting has to be done, that admits of the temporary setting up of a portable machine. Where hydraulic power is applied to movable machines, the high-pressure water is conveyed to the machine by lengths of copper pipe twisted spirally, and having universal joints, which arrangement forms a good elastic connection capable of being turned in any direction. The continuity of the supply to meet the varying positions of the machines is insured by a ball and socket joint, and by a double right-angled joint, as shown by Fig. 41.

Where plate-work has to be put together abroad, the con-

ditions of labour render it difficult to ensure thoroughness of work in rivetting, and it is often worth while to set up a small hydraulic power installation to rivet by these machines, so that the certainty of good work, with the minimum of hand labour, is ensured. Where the transport of the heavy weights for ordinary accumulators is a difficulty, a high pressure on water can be obtained by applying low-pressure water from a cistern to the large (or low pressure) piston of an "intensifying accumulator" already described. By means of a portable engine, water is pumped into the small end of this accumulator, from which it is conveyed by a high-pressure pipe to the machines. A pressure of 20 lbs. per square inch can be obtained on the large end of the piston of the intensifying accumulator with a head of water in a cistern of about 40 feet, and as this water is not consumed, but remains permanently acting on the larger area, no waste takes place. A small tank holding 30 gallons will keep a 6-inch portable rivetter in full work, at a pressure of 1,500 lbs. per square inch.

Hydraulic rivetters are applied with great advantage in shipbuilding, and the results lead to the opinion that the strength of the ships which are thus rivetted is increased. The best authorities are agreed that on machine rivetting the strength of the steamships of the future, with their increasing engine-power, and with the corresponding strains and vibrations, largely depends. By means of hydraulic rivetters, not only is the quality of the work improved, but a labour-saving appliance is employed in a class of work requiring but little skill.

At the London & North-Western Railway Locomotive Works at Crewe, Mr. Webb employs hydraulic rivetting machines to put in practically every rivet in the locomotive boilers and engine side frames. Some years ago he rivetted up one or two pairs of locomotive cylinders with an hydraulic machine, and these have been at work ever since. He considers that work of this kind done by hydraulic machines is superior to, and cheaper than, work done by hand or steam. He ex-

amined some plate work that had been rivetted under a pressure of 47 tons, and it was found that the plates had not suffered at all by the action of the hydraulic rivetter. The "drifting" of the holes, which is necessary in hand rivetting, he considers to be more productive of injury to the plates than any combined squeeze and blow of a hydraulic rivetter. The closeness of the work that hydraulic rivetters turn out has been proved by the fact that some portable boilers made by them have been found to be steam-tight without caulking. The plates in these cases were $\frac{3}{8}$ of an inch thick, and the rivets $\frac{5}{8}$ of an inch. The avoidance of caulking is important, as it prevents the interference with the close contact of the plates, which occurs sometimes in caulking.

The application to a rivet of a combined blow and squeeze (like that obtained from a hydraulic rivetter) prevents the formation of a shoulder on the rivet between the plates, such as is produced occasionally with machine rivetting, when a sharp powerful blow is applied. It is desirable to prevent shoulders, as they involve drilling out the rivet, and the caulking of the joint.

The action of hydraulic pressure in rivetting operations has been well shown by indicator diagrams taken from the pressure cylinders of the Tweddell rivetting machines at the Toulon Dockyard. Professor Unwin pointed out (in a lecture on Water Motors at the Institution of Civil Engineers) some interesting features which were exhibited by these diagrams, as they differ altogether from those taken from an ordinary steam-engine. A steam-engine is actuated by a fluid of comparatively little weight. Water, however, being 500 times as heavy as steam, involves the consideration that its weight acts with, and increases that of, the piston. For instance, in the case of a rivetter worked from a differential accumulator through a 1-inch pipe, the velocity with which the water is forced by the accumulator through the pipe to the rivetter is increased or diminished according to the speed of the rivetter ram, by which the mass of water in the accumulator cylinder

and pipe acts both to increase or diminish the effect produced by the ram. Assuming, as is the case in practice, that the motion of the loaded ram of the accumulator is six times as fast as the rivetter ram, the inertia of the accumulator load is 36 times as great as it would be if it moved at the same speed as the rivetter ram. Further, the force due to the inertia of the water passing into the rivetting cylinder is more than 6,000 times as great as would be the case if the water and rivetting ram travelled at the same speed, owing to the fact that the velocity of the water is 81 times as great as that of the ram. This results in the weight of the ram, which closes the rivet at each stroke, exerting a force of 300 tons.

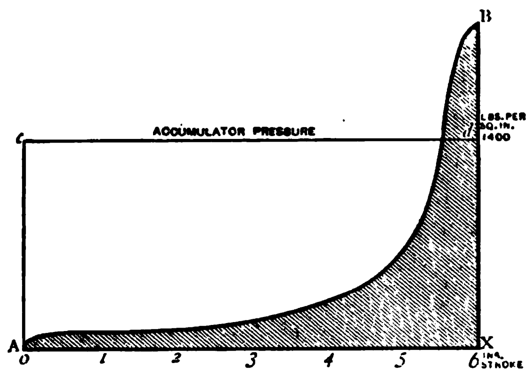


Fig. 42.

Professor Unwin has shown by indicator diagrams the action that takes place in a rivetter cylinder. Fig. 42 is a diagram from a rivetter driven by a differential accumulator through 30 feet of 1-inch pipe. It will be seen that whilst the pressure is least at the beginning of the stroke, it jumps up at the end of the stroke above the accumulator pressure of 1,400 lbs. per square inch, showing the action of the machine to be favourable to the work to be performed, by slowly closing the rivet at first, and then by bringing the maximum pressure, in the form of a squeeze, at the last. The rectangle A *c* *d* X would be the diagram without friction and inertia, but the actual pressure is much less, being only the

shaded part of the figure. Fig. 43 gives an analysis of the friction.

The friction of the cup-leather of the rivetter is shown by the small shaded rectangle A *a b* X, and the friction of the

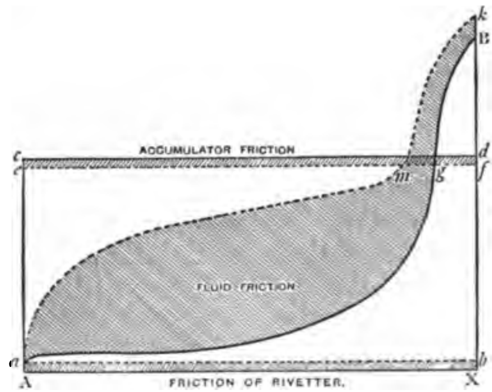


Fig. 43.

packing of the accumulator is shown by the small shaded rectangle *e c d f*. The friction of the water in the 1-inch pipe is shown by the large shaded surface *a m k* B *g*, and this friction maintains the safe working of the machine at about

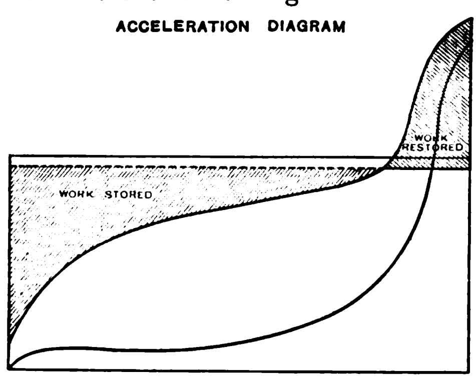


Fig. 44.

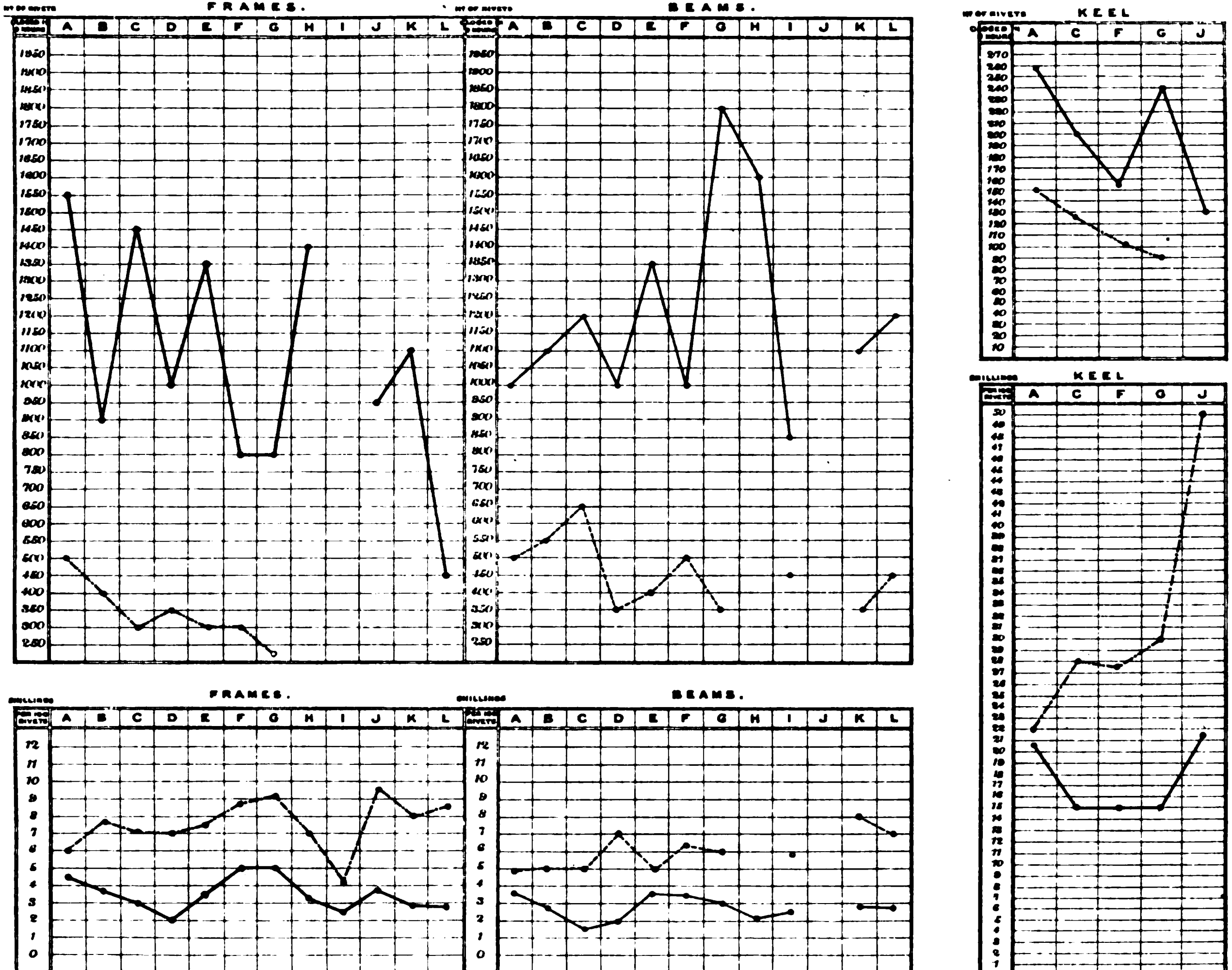
a foot per second. The two blank spaces *a e m* and *m k f* represent the stored work in the first half of the stroke, and the excess of work at the end of the stroke, respectively, which is also shown by Fig. 44.

Rapidity and economy result from the use of hydraulic power in rivetting, as compared with hand labour. Even in heavy work, hydraulic rivetters have put in 1,000 1⅛-inch rivets in 1-inch plates in an ordinary day's work of 10 hours. In portable boiler-work the average rate of working is 7 rivets per minute, and it has been recorded of one machine that it put in an average of 5,000 rivets a day for several weeks. With adequate accumulator power 15 rivets per minute can be put in.

Plate 25 gives the result of a large number of observations as to the comparative speed and cost of work done by portable rivetting machines and hand work. In all cases the hand work is shown in dotted lines and that of the machines in full lines.

The quality, economy, and superiority of the work performed by hydraulic rivetters indicate that it will be universally adopted in the future where water-power is available, or where the permanency of the demand for the power justifies the installation of it. Many interesting experiments have been made by Professor Kennedy on "Rivetted Joints," the results of which have been described in papers to the Institution of Mechanical Engineers. In considering the strength of a joint it is important to notice not only the strain at which fracture takes place, but also that at which the joint begins to give way by slipping. Judged by this standard the machine work was shown to be much stronger than the hand work. In hand rivetting ⅜-inch plates, it was found that slipping began at 27 per cent. of the breaking strain, whereas in the machine joints the slipping did not commence till the strain had reached 59 per cent. of the breaking strain. In the hand-rivetted ¾-inch plates, slipping began at 16 per cent. of the breaking strain, and in the machine-rivetted at 28 per cent. This appears to show conclusively that, regarded from a practical point of view, machine-rivetting possesses very decided superiority over hand work. In these experiments Tweddell's machines were

RELATIVE RATES OF MACHINE & HAND RIVETTING.



RELATIVE COST OF MACHINE & HAND RIVETTING.

Thos Kell & Son, Lith

used, and the pressure upon the rivet-heads was 35 tons per square inch. The loads per rivet at which slipping began were found to be for $\frac{3}{4}$-inch rivets single rivetted by hand $2\frac{1}{2}$ tons, for $\frac{3}{4}$-inch rivets double rivetted by hand 3 to $3\frac{1}{2}$ tons, for $\frac{3}{4}$-inch rivets double rivetted by machine 7 tons. The corresponding loads for 1-inch rivets were 3·2, 4·3, and 8 to 10 tons respectively. It is thought that the load at which visible slip commences is probably proportional to the load at which leakage would occur in a boiler.

HYDRAULIC JOGGLING PRESS.

The nature of the work that is performed in punching holes in plates, and in shearing or bending plates, points

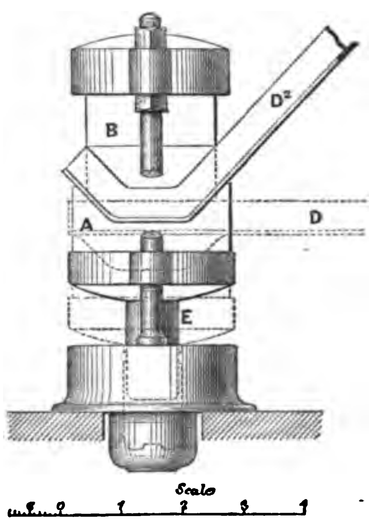


Fig. 45.

to the application of water-pressure to obtain the direct action required for these operations. A machine on this principle, called a "Hydraulic Joggling Press," is shown by Fig. 45.

Suitable dies A and B are fixed in the hydraulic press.

The dotted line shows the bottom table in position, when the angle of the T bar D to be bent is placed on the top of the die A. On the ram E rising, the angle iron is bent between the two blocks into the required form at D^2.

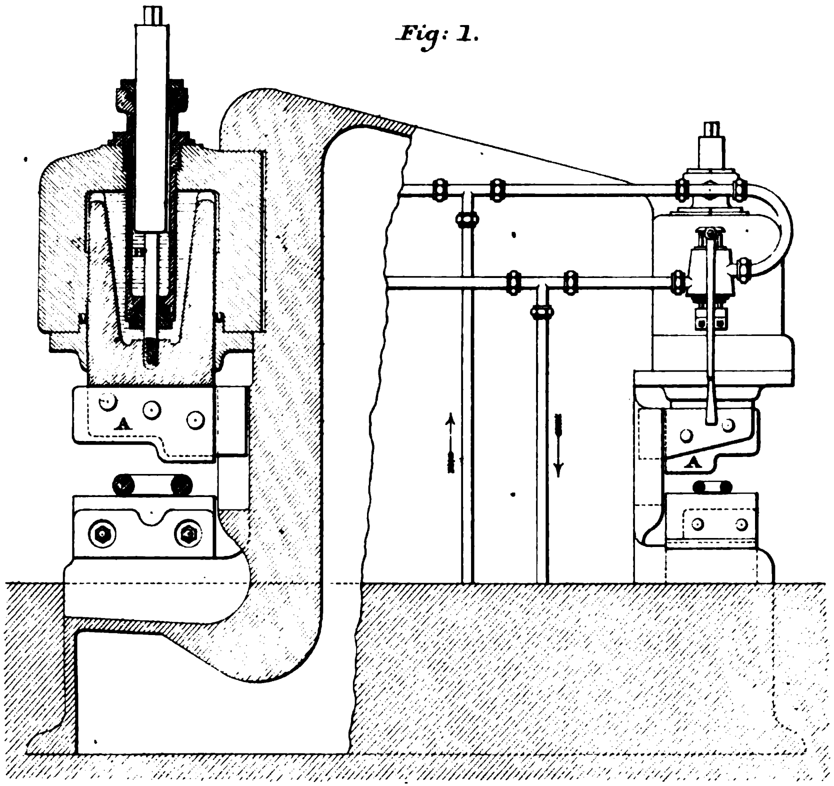
Figs. 1 and 2, Plate 26, show one of Tweddell's machines for shearing chain cables. It will be observed that the knife A is stepped, so that although the cable is cut by one stroke of the machine, it is not done at the same moment. This enables the cylinder to be reduced to one-half the size that would be required were both sides of the cable to be cut simultaneously; and as the pressure employed is usually 2,000 lbs. per square inch, the reduction of diameter that can be effected is a great consideration, as a strong cylinder can be obtained with a moderate quantity of metal. The drawback gear B is also worked by hydraulic power. The machines have two ends, so that any size of cable from 3½ inches to ½ an inch can be cut without changing the knives, or injuring an unnecessary number of adjoining links.

TWEDDELL'S PUNCHING AND SHEARING MACHINE.

Fig. 46 shows a general elevation of a Tweddell triple-punching and shearing machine, capable of punching 1¼-inch holes in 1¼-inch plates, or shearing 1¼-inch plates, or angle-irons 6½ inches by 6½ inches by ⅝ inch. The several tools for performing these different operations are shown on Fig. 46 at A, B, and C. Fig. 47 is partly an elevation and partly a vertical section of the punching-machine. A is the cylinder; B is the piston, which is prolonged by an eccentric stem C, to which is attached the punch-holder D. The stem C, being eccentric to the piston B, maintains the moving tool constantly in its right position relatively to the fixed tool, by preventing any twisting action going on while it is at work. The shoulder L forms a stop. The piston is raised by admitting water

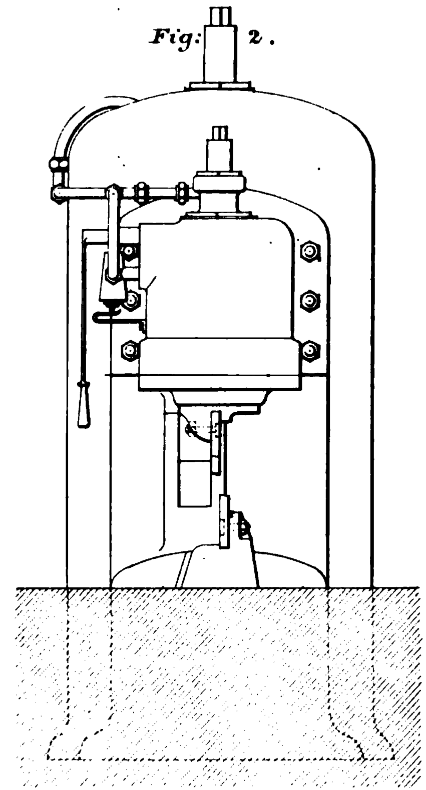
HYDRAULIC CHAIN-CABLE SHEARS.

Fig: 1.



SIDE ELEVATION.

Fig: 2.



END ELEVATION.

Scale 1/20th

Inches 12 6 0 1 2 3 4 5 *Feet*

F. S. Kell & Son Lith

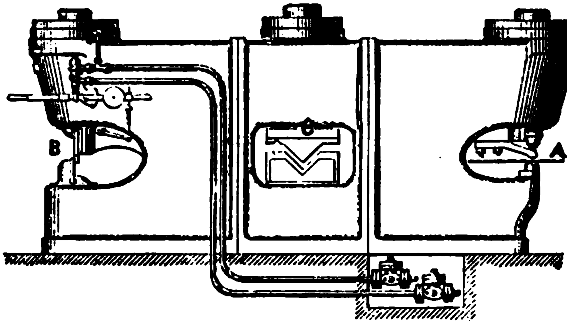


Fig. 46.

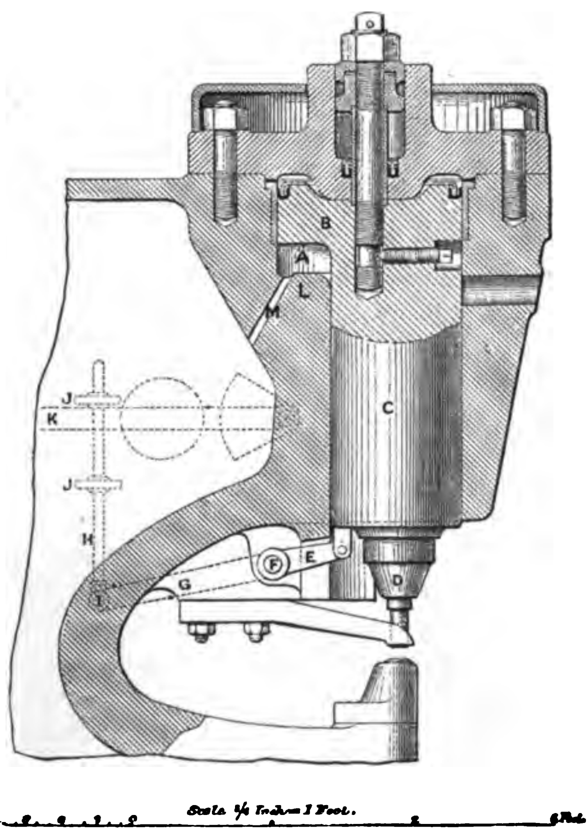


Fig. 47.

through the hole M. E is a lever moved by the stem C, and it actuates the rocking-shaft F, upon the other end of which is a lever G connected by a flexible joint I to the rod H. By means of the adjusting nuts JJ (which strike the valve-lever K) the stroke of the piston can be regulated according to the thickness of the plate that is being punched. The shearing tools shown at B and C are actuated in a similar manner.

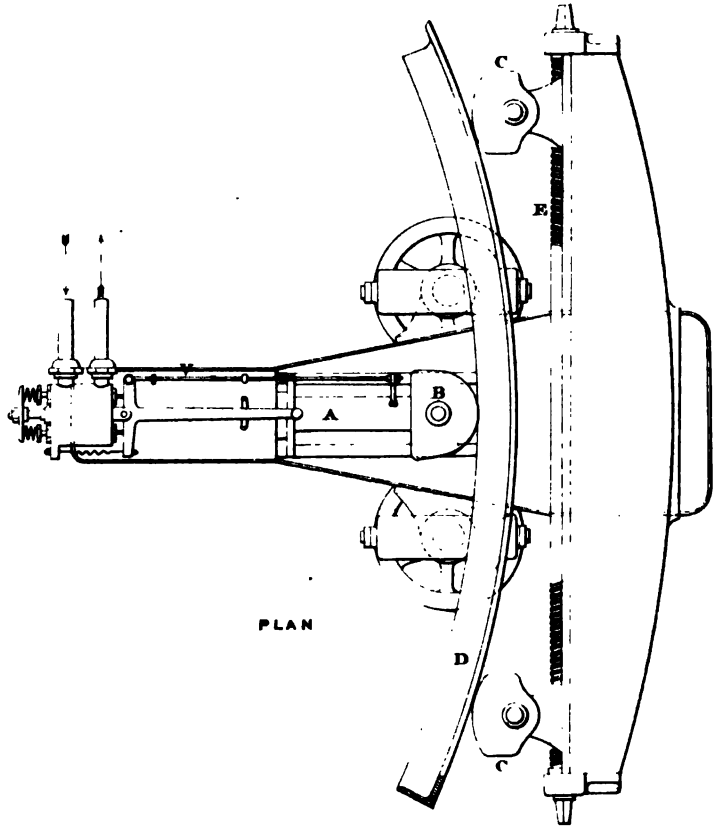
These machines are made of great power to enable dies or punches to be attached for punching large openings in thin plates, and for stamping and moulding. All the dies and knife-holders are made so as to be readily detached, and the necessary moulds applied for cutting and stamping. The knives can be placed at any angle.

A shearing machine, the ram of which has an effective diameter of 14·05 inches and 7·87 inches stroke, requires 1354·75 cubic inches of water to be expended from the accumulator per stroke, and transmits a pressure of 98·42 tons. The maximum work done by the machine per stroke is 144,660 foot-pounds, while the corresponding power developed by the prime mover is 216,990 foot-pounds. In a working day of ten hours the ram would deliver 250 strokes, the volume of water expended would be 196·21 cubic feet and the work expended would be 54,247,500 foot-pounds.

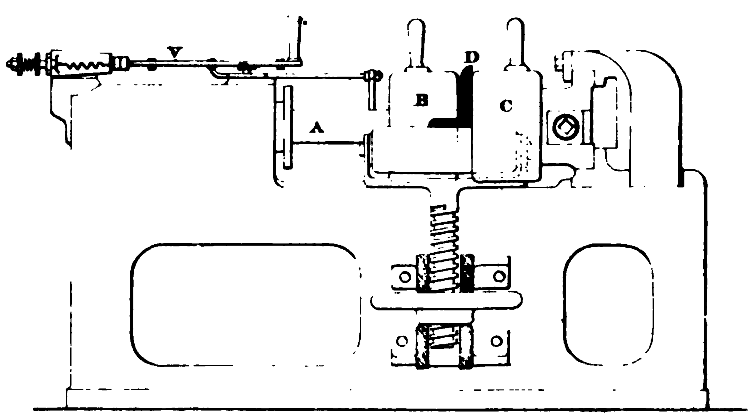
A very complete installation of Tweddell's hydraulic shop tools is that which the French Government have introduced at the iron shipbuilding department at Toulon Naval Dockyard, under the advice of M. Marc Berrier-Fontaine, Ingéniéur de la Marine, Toulon Dockyard. A detailed description of this installation was given to the Institution of Mechanical Engineers. The machines are supplied with water at a pressure of 1,500 lbs. per square inch by means of cast-iron pipes 2½ inches internal diameter, which were tested to double that pressure. The tools are placed on one side of a shop, with gas furnaces on the other, for testing the various plates, angle, and channel irons of ironclads.

5 TON ANGLE-IRON BENDING MACHINE.

PLATE. 27.



PLAN



SIDE ELEVATION.

Scale

Feet

Thos Kell & Son Lith

The machine shown in plan and side elevation on Plate 27 is for angle iron bending at the Toulon Dockyard. The ram A forces the block B against the iron D to be bent, and the positions of the blocks C C (adjustable by the screw-spindle E) determine the curve to be formed. The vertical-screwed rod V has its upper end pinned to the starting lever, and its lower end passes through an eye in the extremity of a horizontal arm carried by the ram of the machine. On the screw are two nuts, one above and the other below the arm, which serve the following purpose:—On the ram rising, the arm strikes the upper nut, and acts on the standing lever with greater force than a man could exert. The exhaust is thus closed, and the upstroke of the ram is arrested. When the ram descends, the arm strikes the lower nut on the screw, which closes the starting valve, and stops the ram in its descent. By adjusting the positions of these nuts, the length of the upward or downward stroke may be regulated to suit the work to be done.

Many years ago, the late Mr. E. A. Cowper employed a hydraulic reservoir, in conjunction with a press, at the works of Sir Charles Fox, to squeeze wrought iron into shape. Some heavy links for the Kief Suspension Bridge were made by means of this press. They were 7 feet 6 inches long, 1 foot 4 inches wide, and 1 inch thick, the eyes and long slots being cut out by the press.

In 1861, Mr. John Haswell employed a hydraulic press of 800 tons for forging parts of locomotives in cast-iron dies, and to him is due the introduction of a press on the Bramah principle, with the addition of a motor, by which a squeeze can be given to the metal.

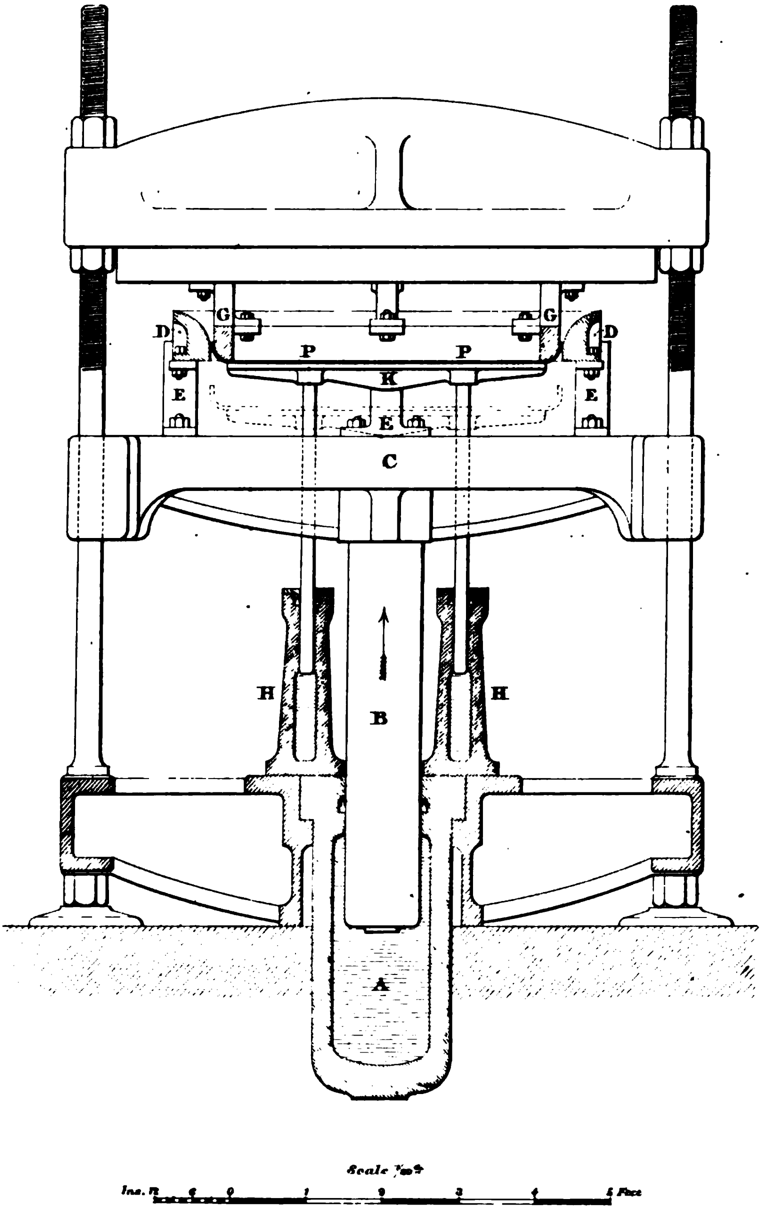
In 1862, Mr. James Tangye described (in a paper read before the Institution of Mechanical Engineers) a simple application of the hydraulic press to shearing and punching. For the former operation, a press carrying a knife edge was connected by bolts to a frame carrying another knife edge. The piece of metal to be sheared was placed between the two

edges, and the press being set in motion by means of a small hand-pump, the knife was forced through it. A bar 3 inches square was cut through in about 2¼ minutes. The shears were well adapted for cutting rails. The action of the punch was of a similar character, and one man could punch an inch hole in a ⅞-inch iron plate in about half a minute. These machines were light and portable, the shears weighing about 14 cwt., the punch 4½ cwt. Mr. Tangye, at the same time, described a hydraulic jack for lifting weights up to 60 tons. Hydraulic power was also employed at his works for stamping purposes, an air-vessel being employed to produce an intensification of pressure.

FLANGING MACHINE.

In applying hydraulic power to flanging and bending plates, it was found, after long trials, that when solid dies were used the cost of the dies and moulds was excessive, but that this difficulty would be got over by means of hollow dies. Mr. Tweddell, in a paper, explained to the Institution of Mechanical Engineers the construction of the Piedbœuf hydraulic flanging machine, which is shown in Plate 28. This machine has a hollow ring die which has the shape of the plate to be flanged. The cylinder A is connected to an accumulator loaded to about 1,500 lbs. per square inch, and the water, acting on the ram B, raises the moving table C, carrying with it the matrix or annular die D, which is supported on small columns E. Some of these are not bolted to the table, but are only slipped in, and can thus be easily taken out when the plate P has been flanged, and requires to be removed. The block G is attached to the top frame, and corresponds to the matrix; and although in this example a round plate is shown, the block and matrix can be made to any required shape. The small auxiliary cylinders H carry on their rams a table K suitable open-

HYDRAULIC FLANGING MACHINE.



ings being made in the main table C to allow of the rams H moving freely up and down independently. The full black line in the drawing shows a plate P at the moment before completion. The dotted lines show it just completed, and detached from the block G, and ready to be removed by taking out one of the columns E. To flange a plate after heating it, the main table C, and small table K, are let down to their bottom position, and the plate being placed on the table K, pressure is admitted to the cylinders H, causing this table to rise up and hold the plate against the block G, which prevents all buckling and risk of unequal flanging. Pressure is then admitted to the main cylinder A, causing the main table C (carrying the matrix D) to rise; the matrix catches the edge of the plate P, and forces it over the block G, as shown. The water is then let out of the cylinders, and the plate is done, the whole operation occupying only about half a minute. M. Berrier-Fontaine has given the following results, which he obtained from a plate-flanging machine at the Toulon Dockyard:—Effective diameter of ram, 15·39 inches. Effective area of ram, 186 square inches. Maximum stroke of ram, 13·78 inches. Maximum volume of water per stroke of ram taken by machine, 2563·05 cubic inches. Expended from accumulator, 2849·87 cubic inches. Effective pressure transmitted by ram, 118·10 tons. Maximum work per stroke of ram done by machine, 303,786 foot-pounds. Expended by prime mover, 455,679 foot-pounds. Maximum per day of 10 hours, 50 strokes of ram, 82·39 cubic feet of water expended, and 22,783,950 foot-pounds of work expended. In using this machine it is necessary to heat the whole plate, and to effect the flanging at one stroke, which involves the use of furnaces and machinery, as well as of blocks and dies large enough to suit different sizes and forms of plates.

Messrs. Tweddell, Platt, Fielding, and Boyd have introduced a machine, which was described in a paper read at the Institution of Civil Engineers, and is shown by Figs. 48 and 49. By means of this machine the flanging can be effected by several

successive operations. The tools employed are simple, and of comparatively small dimensions, and the power exerted (which has to perform only a fraction of the work at a time) is much less than when the whole has to be done at once. In Fig. 48, A B is a bed plate, at one end of which is fixed a frame C, carrying three hydraulic cylinders having plungers D, E, and F, on the ends of which are fixed suitable tools. The two

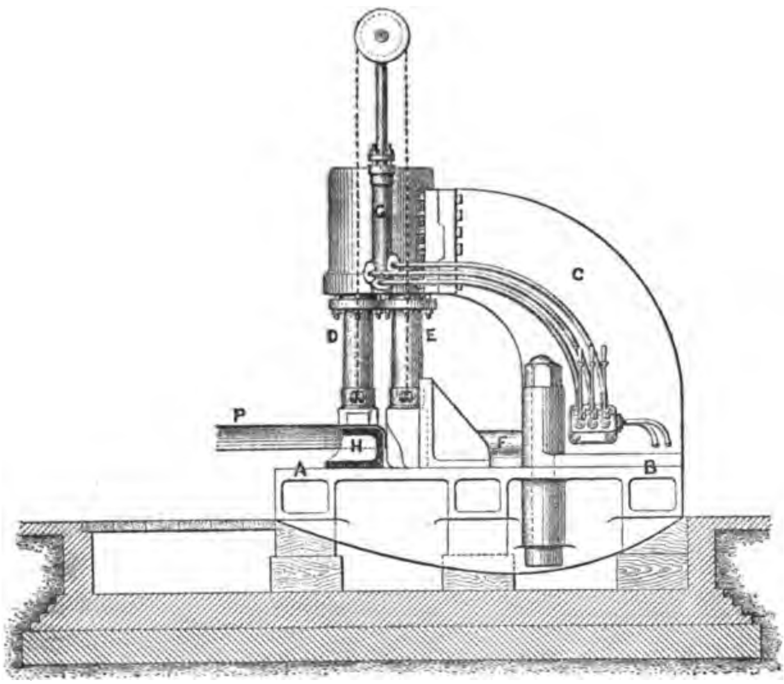


Fig. 48.

plungers D and E, working vertically, may be drawn up by means of chains, worked by the plunger of a drawback cylinder. Should the plate to be flanged be circular, a turn-table is placed in a suitable position, and the anvil block H is also adjusted to the required radius of the flange. The plungers D, E, and F being withdrawn, the plate, which has been heated at the edge, is placed with its edge projecting beyond the anvil H. The plunger D is then lowered upon

the plate, so as to press it firmly on the anvil, and thereupon the plunger E (which carries a tool suitably sloped on its face) descends, and bends parts of the edge of the plate P over the anvil H. The plunger E being now raised, the horizontal plunger F is advanced, so as to press the bent part of the plate against the face of the anvil H. The plungers being again withdrawn, the plate P is turned partly round, so as to present a fresh portion of its edge, which is similarly operated on. Various modifications have been introduced into the

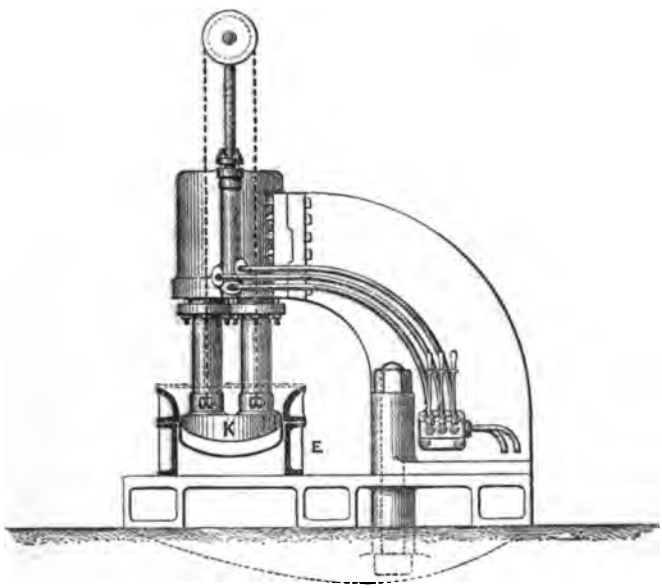


Fig. 49.

machine to suit different classes of work. It can be used for flanging plates in the ordinary way, the two plungers acting together on the moving block K, as shown in Fig. 49.

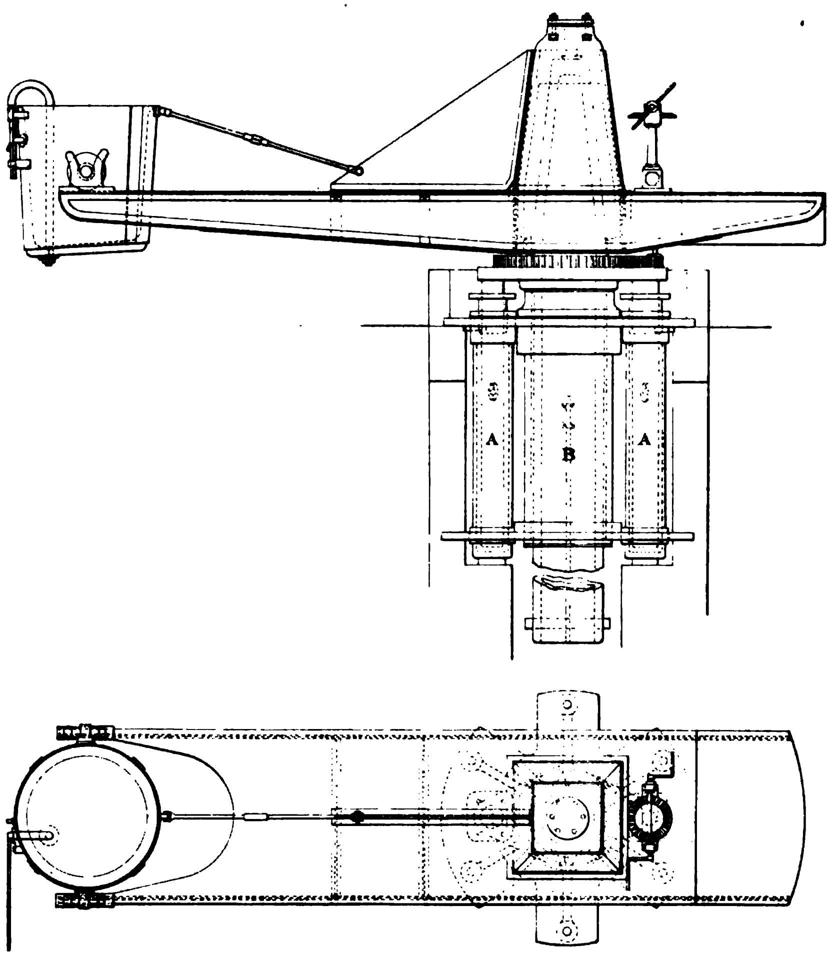
Messrs. Easton & Anderson in 1882 made some experiments on flanging cold steel plates by hydraulic pressure. A pair of moulds were made and fitted to a hydraulic press capable of exerting a pressure of about 250 tons. They were so shaped that at one operation they made a flange both on the outer and inner edges of an annular steel plate, and thus

produced a double-flanged annulus. The upper mould should be formed concave, and the lower convex (to the extent of $\frac{1}{16}$ of an inch), in order to flatten the face of the plate. The plates experimented on were Landore Siemens, of S and SS quality, $\frac{3}{8}$ of an inch thick. Some were annealed and others were not. Mr. Tweddell has recently designed very powerful machinery for bending marine boiler shell plates; the thickest plates can be bent to a true radius to the extreme end.

In a blooming mill at Ebbw Vale, a pair of hydraulic rams under constant pressure are employed to counterbalance the weight of the top roll, by being placed vertically beneath the bed plate of the roll frames, one under each frame. The rams are kept under a pressure of 450 lbs. per square inch, and the diameter being $10\frac{3}{8}$ inches, a constant lifting force of 34 tons is exerted on the top roll, so raising it, and facilitating the entering of the ingot at each passage through the rolls. A tightening down screw, connected with a pinion and toothed quadrant, and actuated by a horizontal hydraulic press, is employed to lower the top roll. One revolution of the pinion suffices for the whole vertical range of the roll. One movement of the handle which controls the admission of water to the press for lowering the top roll, serves to slacken the tightening down screws, the top roll being raised automatically by the pressure on the rams supporting it.

In the Bessemer and Siemens processes for the manufacture of steel, the ingot cranes have to be quickly and easily controlled, with a freedom from gearing, and for this purpose hydraulic power has been adopted as the most convenient. The cranes which are required for the purpose of manufacturing steel have to deal with a different load, and with a different condition of things, to that which formerly existed, as the modern converters produce at each "blow" as much as 12 to 15 tons, compared with a quarter of that weight which was obtained previously. In steel-making, the centre crane is relied on to receive, and distribute, the molten steel in the process, and it has to move a ladle, which must be

12 TONS HYDRAULIC CENTRE CRANE.



Scale.

Inches 12 6 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 Feet.

Thoˢ Kell & Son, Lith.

capable of motion in several directions, in order to accommodate itself to the tipping motion of the converter, which involves a vertical and horizontal motion of a few feet. It must also command a considerable horizontal radius, so as to deliver into the various ingot moulds. The vertical motion is capable of being accomplished by employing a hydraulic ram working vertically in a cylinder, and having a jib or beam resting on the top of, and rising and falling with, the ram. The beam or jib has the ladle at one end, and a counterweight at the other. The horizontal motions are obtained either by hydraulic power, or by hand-gearing.

HYDRAULIC CENTRE CRANE.

Plate 29 is a "Hydraulic Centre Crane" by Messrs. Tannett, Walker & Co., of Leeds, capable of lifting 12 tons. The radius is 17 feet, and the stroke or vertical lift is 7 feet. There are two rams AA (9 inches in diameter), in communication with the accumulator, nearly balancing the dead load of the rams, jib, ladle, &c. Sufficient margin is allowed to admit of the crane descending and forcing back into the accumulator the water that is displaced by this ram. A third ram B (12½ inches in diameter) is under the control of the workman by means of a valve, which can be placed either close to the crane or at a distance from it. In this case the turning is done by hand, but it is often performed by a hydraulic engine. The two side rams effect a saving of water-power, and enable the crane to be made of any desired strength, without involving the loss of power that occurred in the old form of crane.

WRIGHTSON'S BALANCE CRANE.

Mr. Thomas Wrightson has designed a good form of balance crane to meet the difficulty of dealing with the strains in a

heavy 15-ton casting crane. This is shown by Fig. 50. The crane post revolves on a pivot, and carries the cylinder with it, in its horizontal rotation, by means of a key. Frames for the sheaves are fixed on the ram, and revolve with it. The top support for the ram is attached to the roof, the maximum horizontal strain not exceeding 4½ tons. The lifting cylinder has a 21-inch gland at the bottom, and a 12-inch gland at the top. This cylinder works up and down upon the post, the

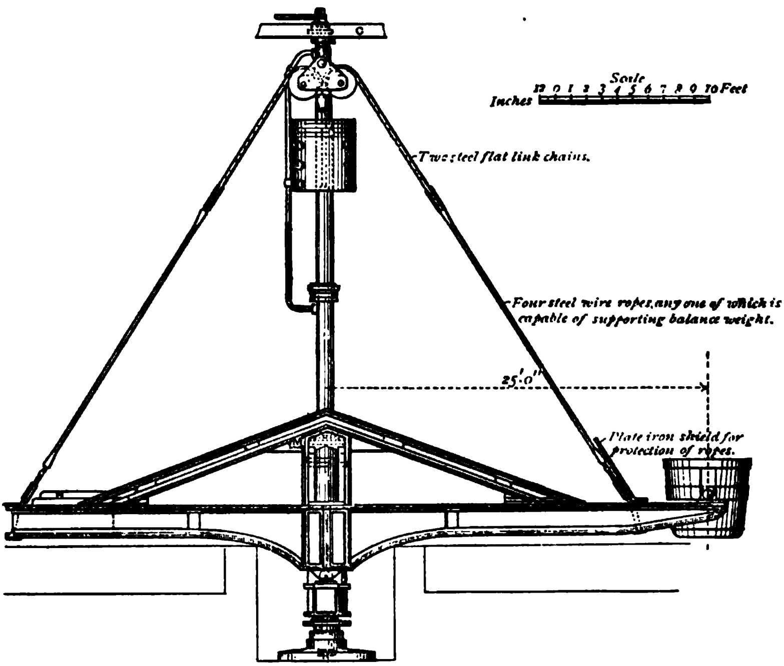


Fig. 50.

top gland of the cylinder working in the smaller diameter, and the bottom gland working in the larger diameter, of the post. Thus when water is admitted into the cylinder (through a hole in the post) the cylinder itself rises with a lifting power equal to the difference of the two areas of the post, multiplied by the effective pressure of the water. Further, by flattening one side of the post at the larger diameter, and adapting the lower gland-box to this form, a sliding-key

arrangement is produced, so that for horizontal rotation, the cylinder and post move round together. The machinery and ladle are carried by a cradle with a pivot fixed at the bottom of the cylinder, on which the cradle has a slight rocking movement. The ladle when full contains 12 tons of steel. A weight is adjusted so as to balance the cradle when the ladle contains half its charge, or 6 tons of steel. A revolving port on the top of the crane post conveys water to and from the cylinder. A stop is provided to prevent the cradle from drooping when the preponderance of weight is on the ladle end, but if the bottom of the ladle be lowered upon anything unyielding, the frame simply hinges upwards on its pivot. The pipe conveying water to and from the cylinder is arranged so that the lower end terminates in a hole which is bored through the centre of the ram, the upper end also entering the post to convey water through the top bearing.

It will be seen that provision has to be made to balance the half weight of the steel, which is not balanced by the counterweight. To accomplish this, chains are led from each end of the girders forming the platform, over sheaves fixed on a strong frame at the top, and forming part of the crane post immediately under the top socket, so that the sheave frame can rotate horizontally with the crane post and cylinder. The two sets of chains, after passing over their respective sheaves, descend to a heavy balance weight of annular form, surrounding the upper portion of the crane post, which acts as its guide. The point of connection of both sets of chains is the same, and is in a plane passing through the centre of gravity of the weight, so that it may hang indifferently on either one or the other set of chains. The chains are a succession of flat steel links connected by pins.

If the ladle is half full, then the fixed counterweight balances this amount of steel, and the annular balance distributes its weight equally between the two sets of chains, neutralising so much of the dead weight of the platform, and so saving water pressure in the cylinder. If the ladle is full,

the half weight tends to bring down the ladle end of the platform, but is prevented (owing to its rigidity), without the opposite end being raised to an equal extent. The depression of the ladle end, therefore, tightens its chains, whilst the elevation of the opposite end slackens its chains. By this means the whole weight of the annular balance comes on the tight chains of the ladle end, and thus any preponderant weight in the ladle is balanced automatically.

As the steel is run into the ingot moulds, the preponderance becomes less, until when more than half is run out, the preponderance is transferred to the opposite end of the platform. As this takes place, the opposite chains are tightened by the action of the fixed balance weight, until, by the time the whole of the steel has run out of the ladle, the entire weight of the annular balance is hanging on the set of chains opposite to the ladle, and in fact balances the whole effect of the fixed weight on the platform. This transmission of the forces is entirely automatic; the annular balance, by means of this special mechanical arrangement, divides its weight between the two ends of the platform, in the exact proportions required to maintain equilibrium, and this without affecting any of the other motions of the crane, which may be going on at the same time.

HYDRAULIC POWER AT THE FORTH BRIDGE.

Sir B. Baker (the President of the Mechanical Science Section of the British Association in 1885) acknowledged the important part that hydraulic appliances had played in the construction of the Forth Bridge in the following words:— "More than 42,000 tons of steel plates and bars have to be bent, planed, drilled, and rivetted together before or after erection, and hydraulic appliances are used throughout. The plates are handled in the shops by numerous little hydraulic cranes of special design, without any complication of multi-

plying sheaves, the whole arm being raised with the load by a 4-inch direct-acting ram of 6-feet stroke. A total length of no less than 60 miles of steel plates, ranging in thickness from 1¼ inch to ⅜ inch have to be bent to radii of from 6 feet to 9 inches, which is done in heavy cast-iron dies squeezed together by four rams of 24 inches in diameter and the same stroke. With the ordinary working-pressure of 1,000 lbs. per square inch, the power of the press is thus about 1,750 tons. Some 3,000 pieces, shaped like the lid of a box, 15 inches by 12 inches wide, with a 3-inch deep rim all round, were required to be made of ½-inch steel plate, and this was easily effected in two heats by a couple of strokes of a 14-inch ram." He also described that, in erecting the great 1,700 feet spans of that bridge, the massive girders were put together at a low level, and were hoisted as high as the top of St. Paul's Cathedral, by hydraulic power. Continuous girders, nearly one-third of a mile in length, were similarly raised, together with the necessary sheds, cranes, appliances, and workmen, the whole weight on the platforms being in some instances more than 1,000 tons.

In the excavation of the foundations of the Forth Bridge hydraulic appliances of a novel kind were used. The huge wrought-iron caissons (70 feet in diameter and 70 feet high) for the foundations had to be sunk through tenacious boulder clay, which was excavated by hydraulic spades. Hydraulic rams worked in the hollow handles, which were thrust against the roof, and by turning a tap the spade was forced into the clay, with a pressure of three tons. These hydraulic spades were employed in an electrically lighted diving-bell 70 feet in diameter, 7 feet high, and 90 feet below the sea.

CRANES.

In all the designs for hydraulic cranes, the principle employed is that of using the direct thrust of a ram or

piston through a short stroke, and multiplying the stroke by carrying the lifting chain over a series of sheaves. In general, the cylinders and machinery are placed horizontally in a chamber underground. In some cases the lifting cylinder is placed vertically, and is made to form part of the pillar of the crane, as is shown by Plate 30, Fig. 1, which represents a goods station crane for a lofty goods shed, the pillar being carried by top and bottom bearings. The lifting cylinder is placed in the pillar of the crane, to which pillar the working valve is fixed, the water entering and escaping through the pivot as shown by Fig. 2.

A form of station crane is shown by Plate 31, which represents one of the cranes erected at the new goods station of the North-Eastern Railway at Newcastle-on-Tyne.

Plate 32 shows an Elswick "Movable Hydraulic Crane."

When the load to be raised becomes very great (100 tons or so), it is better to substitute some other arrangement for that of chains. In the case of a large crane which Sir William Armstrong, Mitchell, & Co. erected at the Royal Italian Arsenal at Spezzia, the lift is performed by the direct action of a piston contained in an inverted cylinder suspended in gimbals from the head of the jib, as shown by Plate 33. This crane is capable of lifting 160 tons through a range of 40 feet. It is carried upon a ring of live rollers supported by a pedestal of masonry, and the slewing is effected by a hydraulic engine applied to a pinion gearing into a circular rack. The jib projects 65 feet from the centre of rotation, and its height above the quay level is 105 feet. If the crane is used to lift much lighter loads than the maximum, a chain is employed, which is raised and lowered from a cupped drum, worked by the slewing engine.

HYDRAULIC GOODS CRANE. PLATE. 30.

Fig 1.

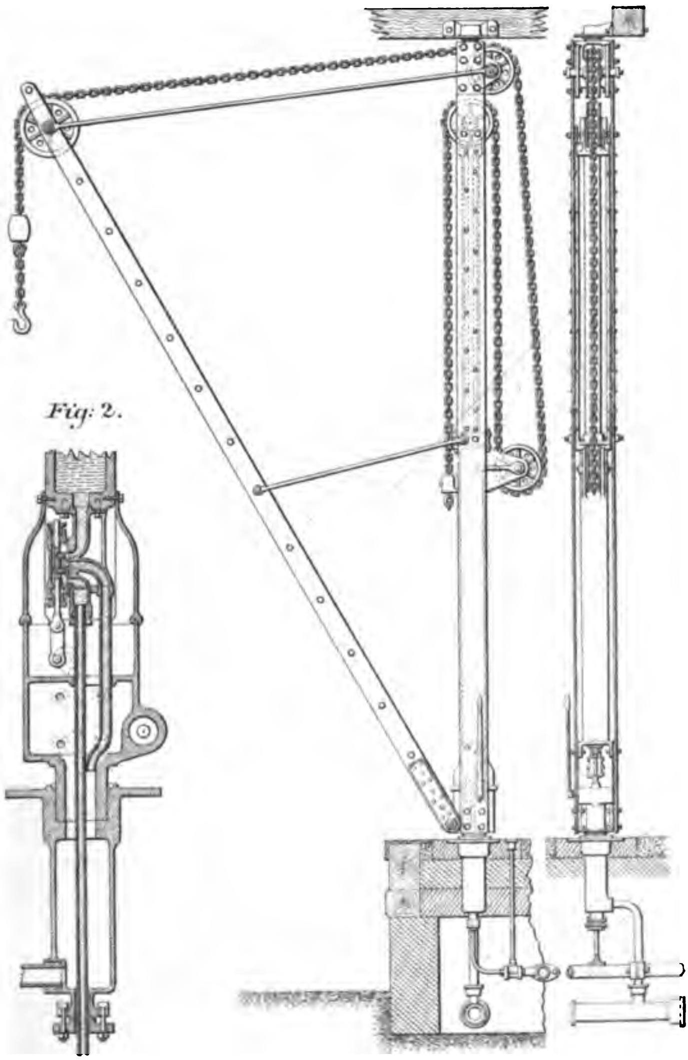
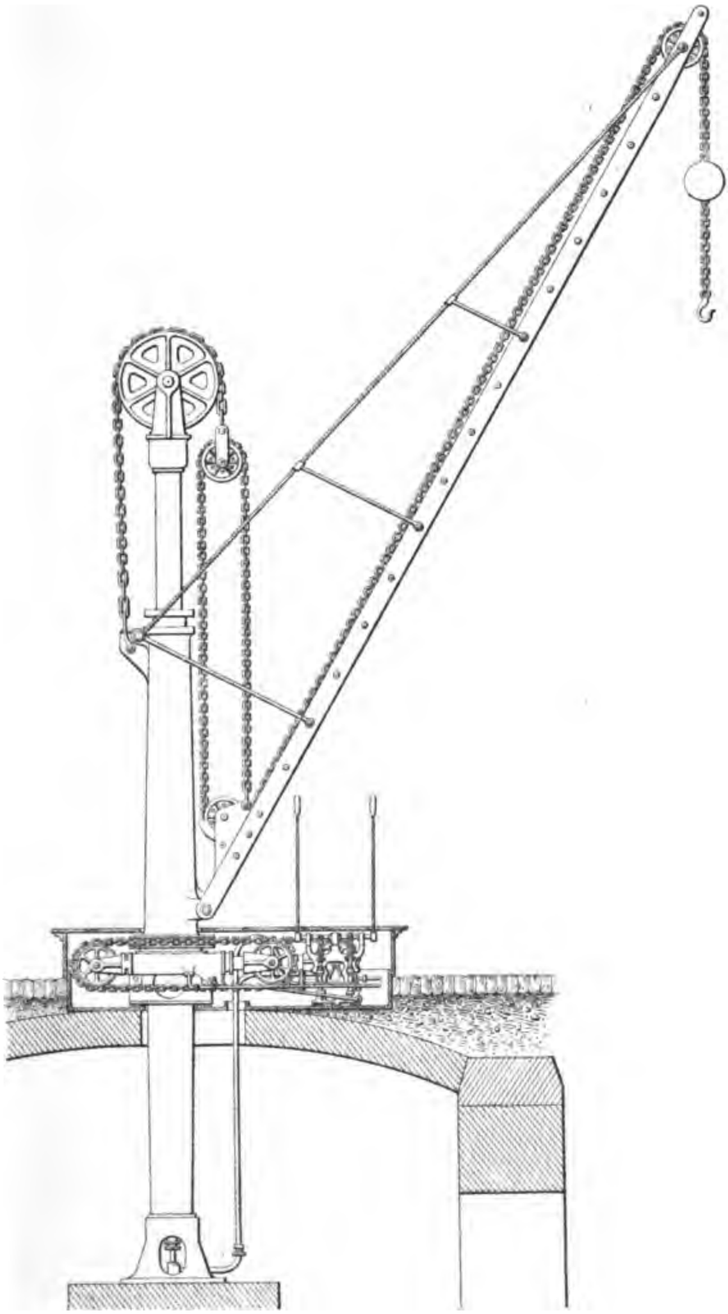


Fig: 2.

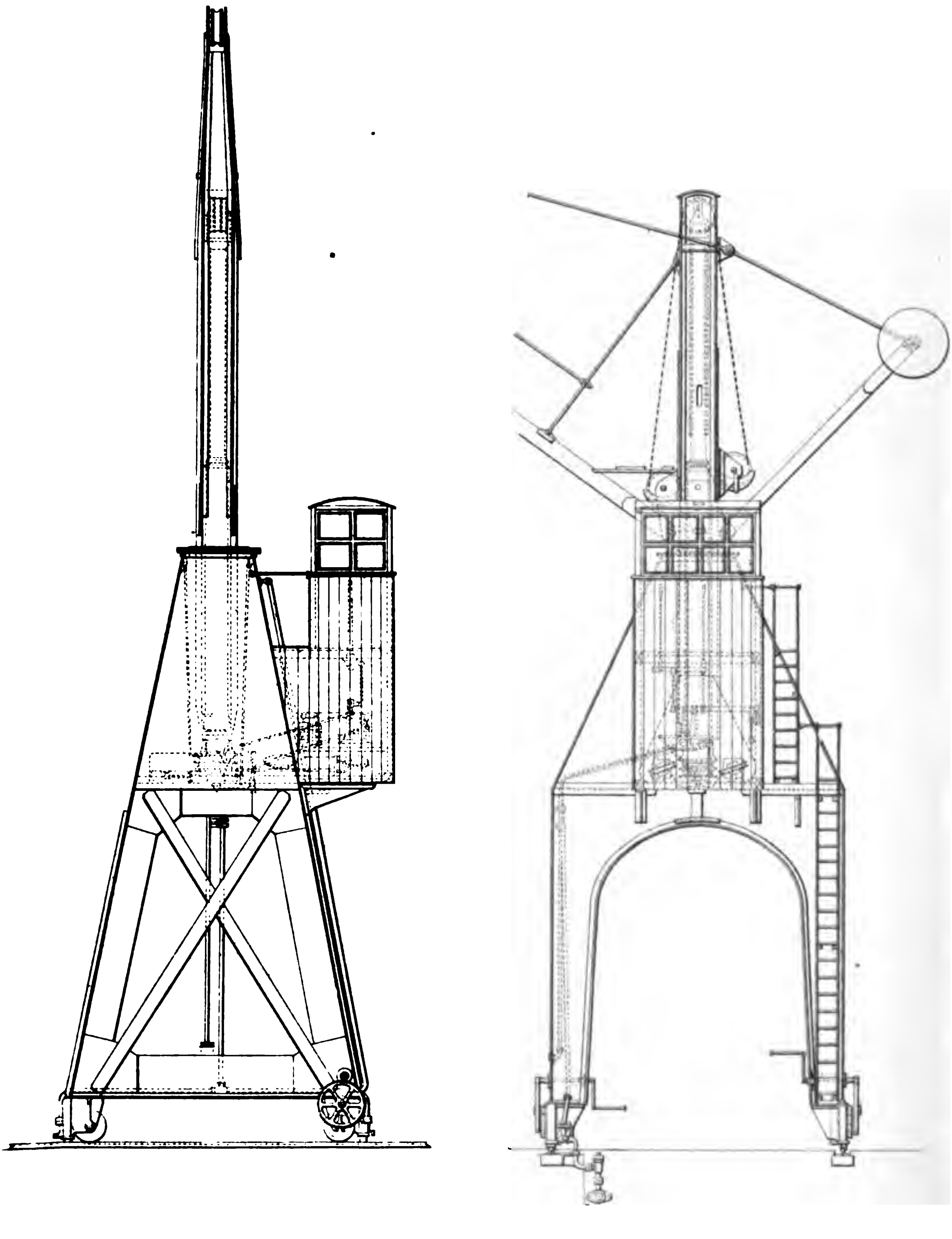
T. Kell & Son, Lith.

STATION CRANE.



Thos Kell & Son Lith.

MOVEABLE HYDRAULIC CRANE.

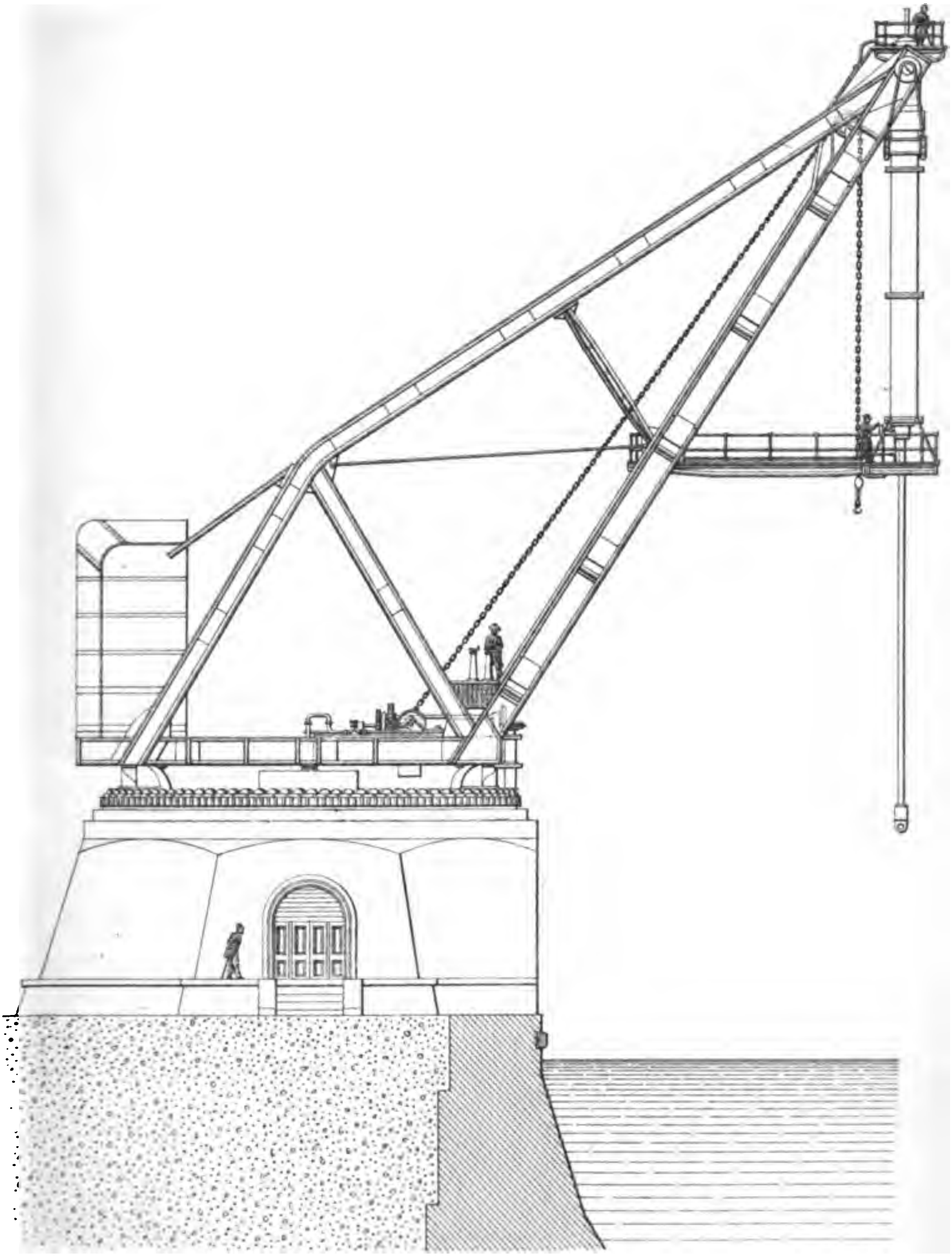


Scale ½ Inch 1 Foot.

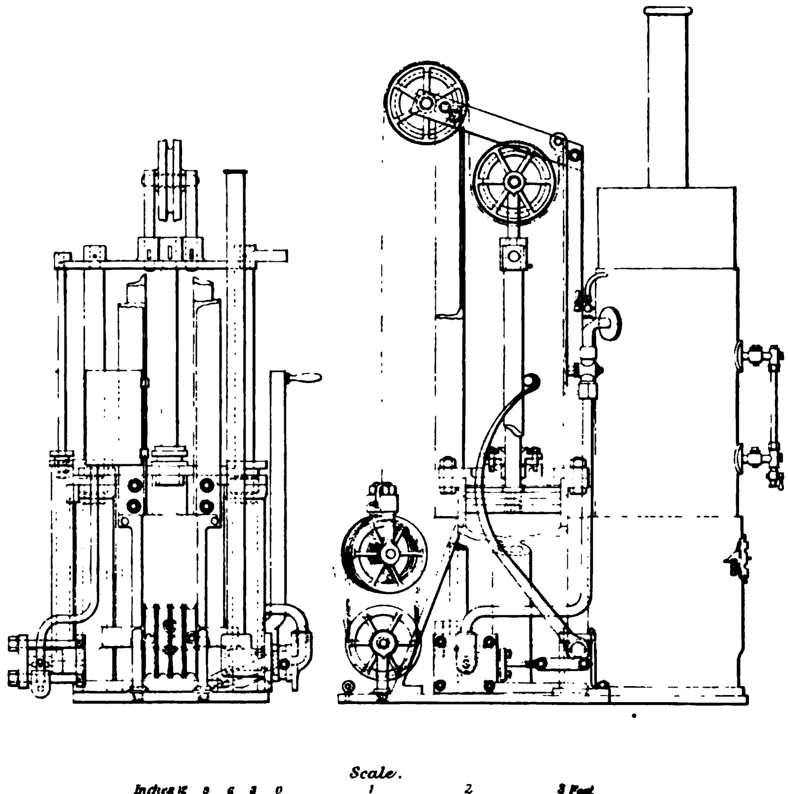
Inches 12 6 0 1 2 3 4 5 10 15 20 Feet

CRANE AT ITALIAN ROYAL ARSENAL.

PLATE. 33.



COAL WHIPPING MACHINE.



Thoˢ Kell & Son, Lith

HYDRAULIC COAL-DISCHARGING MACHINES.

In the year 1851 Mr. (now Lord) Armstrong directed his attention to the substitution of some mechanical arrangement for discharging coal from colliers in the Thames in lieu of "hand-whipping" and he designed the coal-whipping machine which is illustrated by Plate 34. The load is raised by one stroke of a steam-piston acting through multiplying sheaves on the lifting-chain. At each side of the steam cylinder there is a cataract plunger attached to the crosshead of the steam-piston, and the descent of the load is regulated by a valve, which controls the passage of the water from the cataract cylinders to a small cistern above them. A vertical multitubular boiler supplies the necessary steam. The upper side of the piston is in constant communication with the boiler, and when it is desired to make a lift, the lower side of the piston is, by the movement of the starting-valve, opened to the exhaust. In lowering, the steam-piston is placed in equilibrium by admitting steam to the under side, and the descent of the load is controlled by the valve on the cataract cylinders. A tappet on the crosshead automatically shuts the starting and cataract valves at each end of the stroke. A feed-pump for supplying the boiler with water is also attached to the crosshead.

About the same time that the above machine was introduced on the river Thames, the Glamorganshire Canal Company took steps to improve the method of discharging coal, which resulted in the fitting up of two hydraulic machines at Cardiff. A wooden frame was placed at a sufficient distance from the quay to enable a truck of coals to stand between it and the latter. The coals were discharged from the barges or vessels on the canal by a bucket, which was raised and lowered, swung inwards or outwards, by means of a vibrating jib, all the operations being performed by hydraulic power. The action of these vibrating

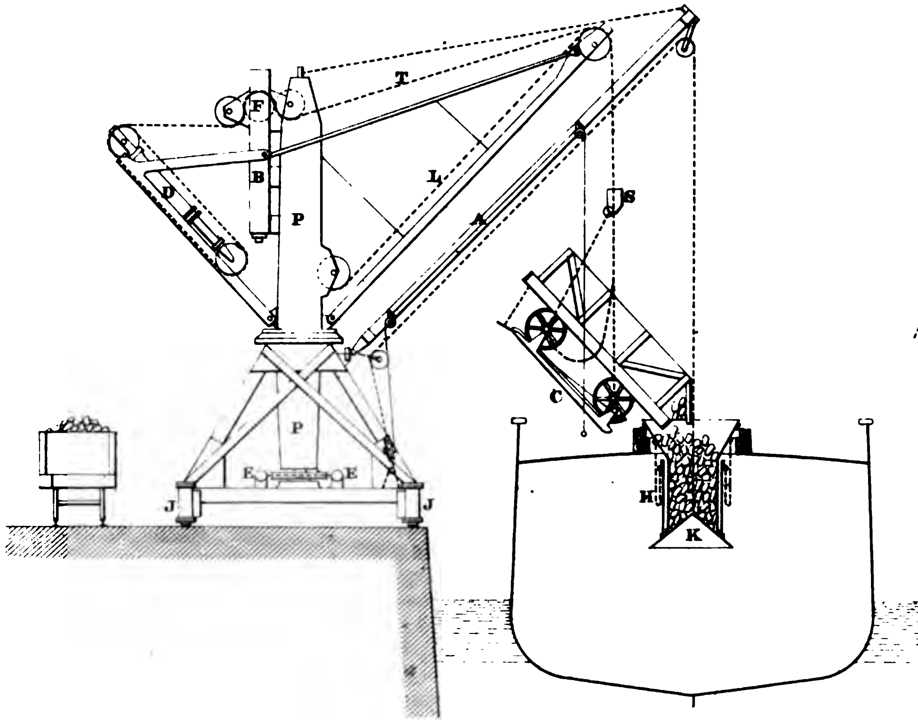
jibs (which were afterwards used on a larger scale at Swansea and Poplar) was controlled at the extreme end of the stroke by a tapered rod closely fitting the aperture through which it passed.

The most recent development of the system may be exemplified by the movable hydraulic crane devised by Mr. Westmacott, and erected by the Armstrong firm, at the Bute Docks, Cardiff. A description of this was given by Mr. M'Connochie at the Cardiff meeting of the Institution of Mechanical Engineers in 1884, and is shown by Plate 35. The shipping of coal direct from the trucks had previously been carried out by fixed hydraulic cranes. It was, however, found that the work could not be done rapidly enough, as the fixed cranes could only load into one hatchway of a ship, since the positions of the hatchways in steamers varied so much that the cranes could not be placed to suit different vessels. Movable cranes were decided upon to obviate this hindrance to rapid working; but, as the cradle or platform on which the truck was lifted required a pit in the line of rails for its reception, a crane could only pick up waggons at one point. To meet this difficulty, Mr. Westmacott designed the coaling cradle C, shown by Fig. 1. It consists of a light platform suspended by chains capable of being placed in any position upon a line of rails. The platform is permanently hung by chains from an anti-friction swivel S (shown to a larger scale in Figs. 4 and 5), which enables a man to turn the cradle with a loaded waggon on it, thereby dispensing with turntables.

The crane is carried on a nearly square wrought-iron pedestal, which runs on four wheels upon a line of rails of 24 feet gauge. There are also four lifting jacks J J, one at each corner, which take the weight when the crane is at work. The pillar P P consists of two flat plate girders which revolve in bearings at the top and bottom of the pedestal. There are three hydraulic cylinders for lifting and tipping; the first is placed between the girders of the pillar

MOVEABLE HYDRAULIC CRANE.

Fig: 1.



SIDE ELEVATION, SHOWING MODE OF TIPPING.

Fig: 4.

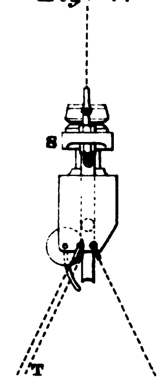
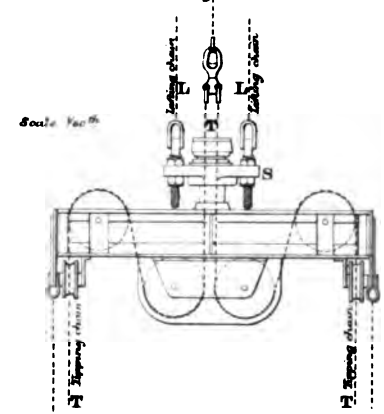


Fig: 5.



SWIVEL ATTACHMENT.

Fig: 2.

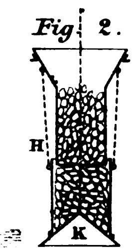
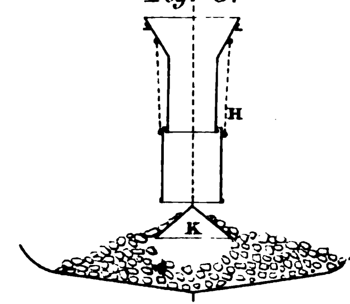


Fig: 3.

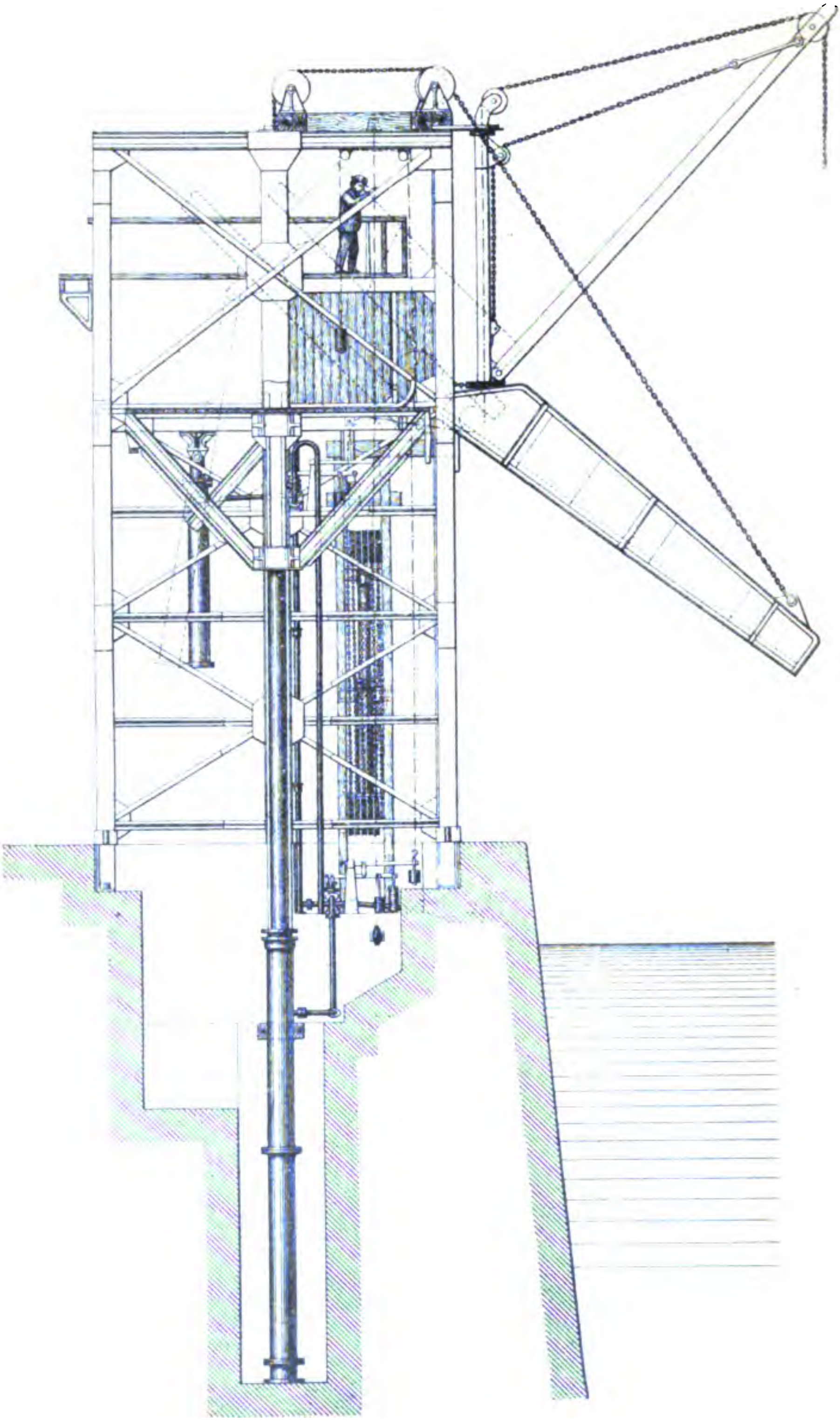


TELESCOPIC HOPPER.

Scale 1/100th

Feet 10 5 0 10 20 30 40 50 Feet

Thos Kell & Son, Lith.



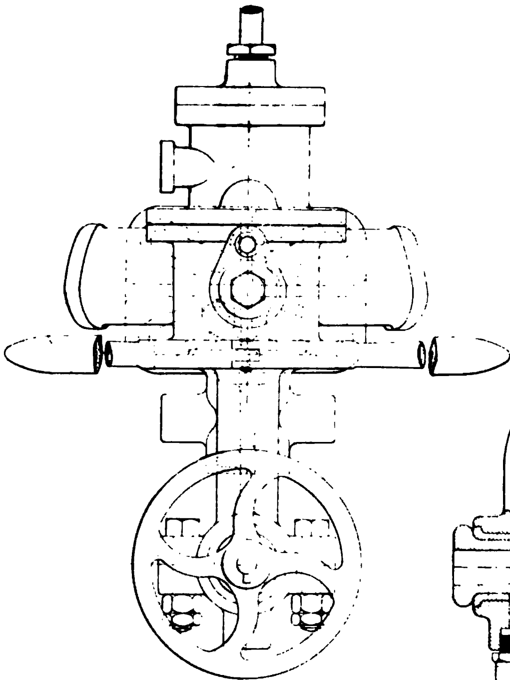
West, Newman Photo

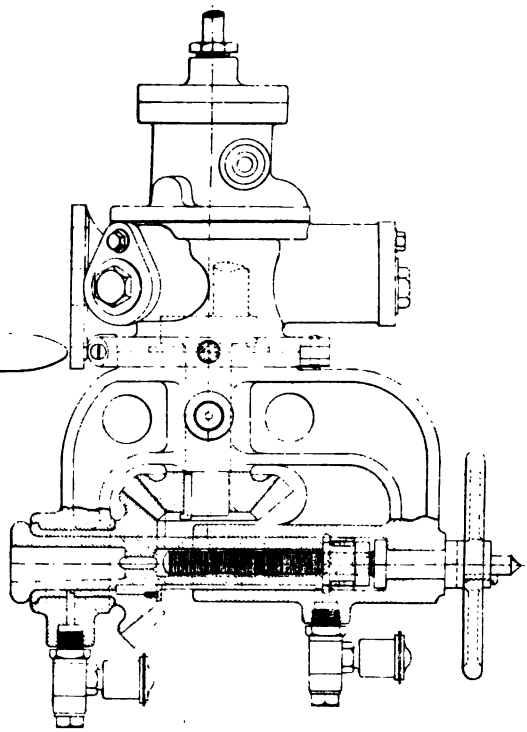
for lifting the load by means of the chain L, the two ends of which are made fast to the swivel attachment S. The second, D, is for tightening the tipping chains T, and the third, B, is for effecting the tipping, by making a bight in the tipping chain (as shown at F), while the cylinder D is locked by its valves. The pillar is turned by two horizontal hydraulic cylinders, E E (one on each side of the pillar), fixed to the pedestal, and working a chain which passes round a drum at the foot of the pillar. All the motions are readily controlled by one man in a valve-house fixed to the pedestal (not shown on the Plate). Two such houses are provided, on opposite sides of the crane, so that the man can use whichever is most convenient for watching the operations. The pressure water is conveyed to the crane by movable jointed pipes, which can be attached to hydrants placed at convenient distances on the hydraulic mains along the quay wall. There is an auxiliary or anti-breakage crane, A, on the side next the dock, for working a hopper, H, resting on the deck of the ship. This hopper (designed by Mr. Charles L. Hunter, of the Bute Works) has a telescopic throat of square section, which is closed by a pyramidal bottom, or valve, K, held up by the auxiliary crane A. The object of this is to allow the first few truck-loads of coal to be lowered gently to the bottom of the hold, so as to lessen the breakage of the coal (as shown in Figs. 1 and 3). When not in use, this crane can be swung to the side, out of the way. A waggonful of coal can be shipped in from 2½ to 3 minutes.

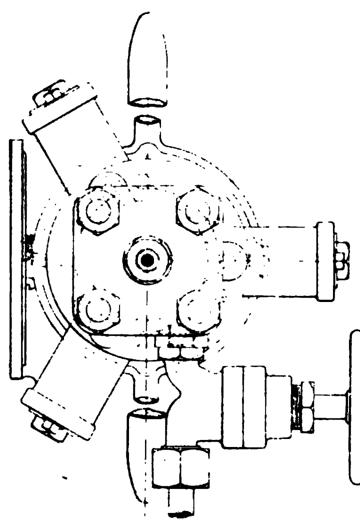
To avoid the breakage of the coal by discharging it into coal ships by shoots direct from the coal trucks, many mechanical arrangements have been used, the most perfect of which are the hydraulic coal hoisting machines that were introduced many years ago by the Armstrong firm. An illustration of them is given on Plate 36, which is taken from the *Proceedings of the Institution of Civil Engineers.* In order to minimise the breaking of the coal, it is desirable, as before stated, to form a heap in the hold of the ship by lowering some coal

9

at the outset, either by a hydraulic crane or otherwise, and afterwards to provide for the discharge of the bulk of the coal slowly upon this heap, instead of delivering it with a rush. The apparatus shown meets these requirements, and is applicable to low-level railway and flat-bottom waggons. The waggon is lifted upon a cradle resting on the top of an hydraulic ram, the coal being tipped into a shoot (large enough to hold a waggon-load of coal) which rises or falls, to meet the varying height of the deck, by connecting the shoot with the cradle, which ensures the right level being obtained. To regulate or stop the flow of the coal in the shoot, a pair of doors is fixed across its mouth. The coal is discharged by tipping the waggon by a hydraulic press, mounted on trunnions, which travels with the cradle and raises the back of the platform (which is hinged in front) to the desired inclination. The various movements are governed by valves, worked by a man stationed on an elevated platform commanding a view of the operations. The waggons are brought to, and removed from, the coal-tipping apparatus by means of hydraulic capstans, turntables, or traversing machines, according to circumstances. A great number of coal hoisting machines, based on this principle, are in use wherever the expeditious transference of coal from waggons to ships is requisite. Where coal is brought by canal (as at Goole) for shipment, an arrangement is in operation by which a number of separate barges, each containing 32 tons of coal, are united, so as to form compartments of one long vessel. On entering the dock, the sections are disconnected, and each compartment is brought under a direct-acting inverted cylinder and piston, which lifts it bodily out of the water; afterwards it is tipped by a small hydraulic engine into a shoot, which delivers the coal into the ship.





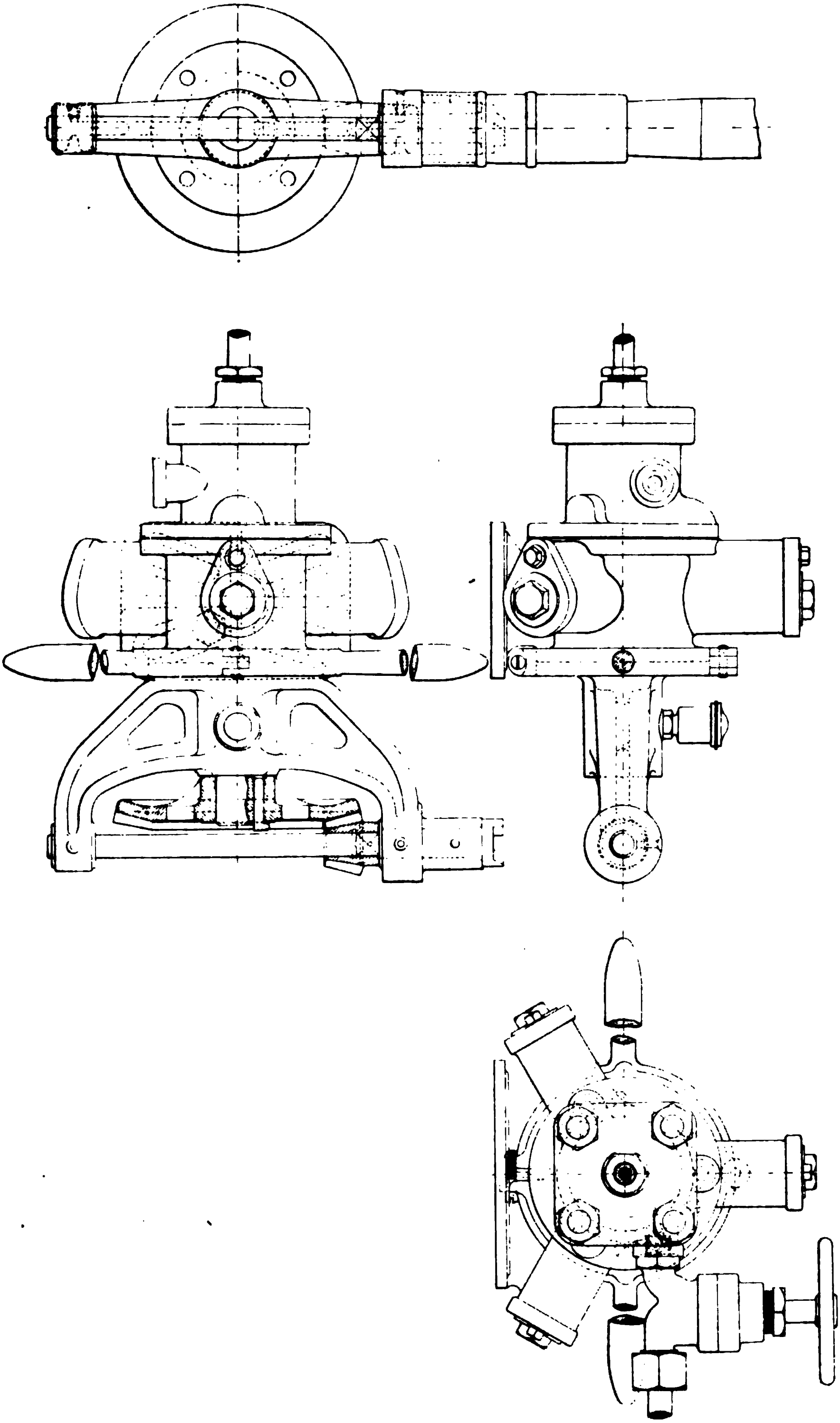


West, Newman Photo.

HYDRAULIC ENGINE,

PLATE 38.

WITH STOWE SHAFT ATTACHMENT.



West, Newman Photo.

HYDRAULIC DRILL.

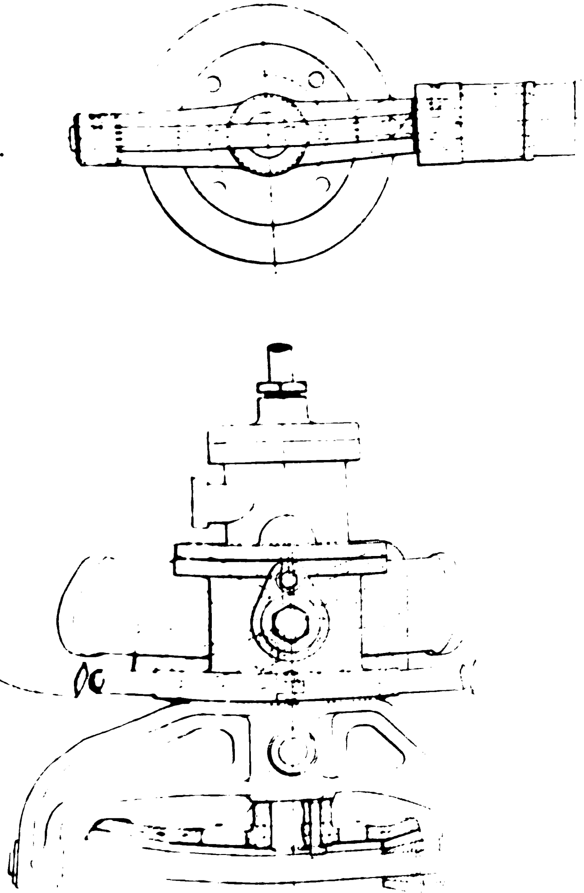
Plate 37 shows a Marc Berrier-Fontaine direct-acting hydraulic drilling apparatus. It consists of a Brotherhood three-cylinder hydraulic engine connected directly to the drill press. The apparatus is made in various sizes and forms. The one illustrated has cylinders $1\frac{3}{16}$ inches diameter with a stroke of $1\frac{3}{16}$ inches, and is designed for working pressures up to 1,500 lbs. per square inch, being capable of drilling holes of $1\frac{1}{4}$ inches diameter in iron or steel, the drill spindle having a feed of 4 inches. The apparatus is provided with clip handles, so that it may be readily fixed in any required position. The pressure water for driving the engine, and the exhaust water from it, are conveyed through flexible tubing, a stop valve being fixed on the valve chest to regulate the running of the engine. This machine is well adapted for structural work, such as for boilers, girders, &c., and also for use in shipyards for drilling holes in place during construction. The machine that is illustrated weighs about 85 lbs. A larger size, which is capable of drilling holes up to 2 inches diameter, weighs about 110 lbs.

Plate 38 shows another form of the apparatus, the motor and drill press being separated, the power being conveyed through a flexible shaft. In this case the engine is bolted to a driving attachment, to which one end of the flexible shaft is connected, the other end being connected to the drill press. This form of the apparatus allows of the engine remaining in one place whilst any number of holes may be drilled within the range of the flexible shaft, the drill press only being moved from hole to hole. The apparatus like the direct drill is provided with handles for carrying about.

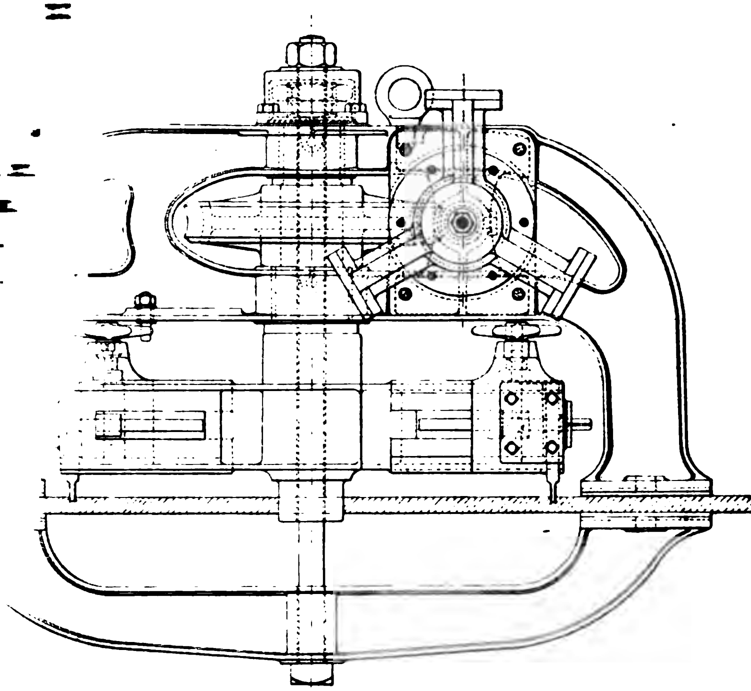
MANHOLE CUTTER.

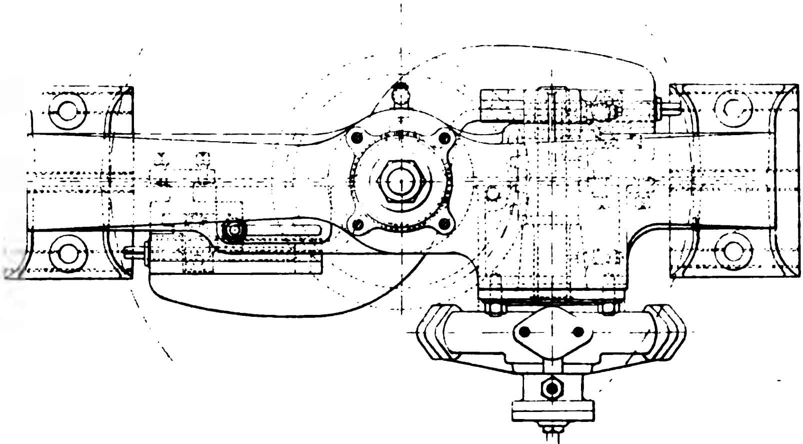
Plate 39 shows a Marc Berrier-Fontaine hydraulic manhole cutter for cutting circular or oval manholes of any diameter

HYDRAULIC ENGINE
WITH STOWE SHAFT ATTACHM



·RAULIC MANHOLE CUTTER.





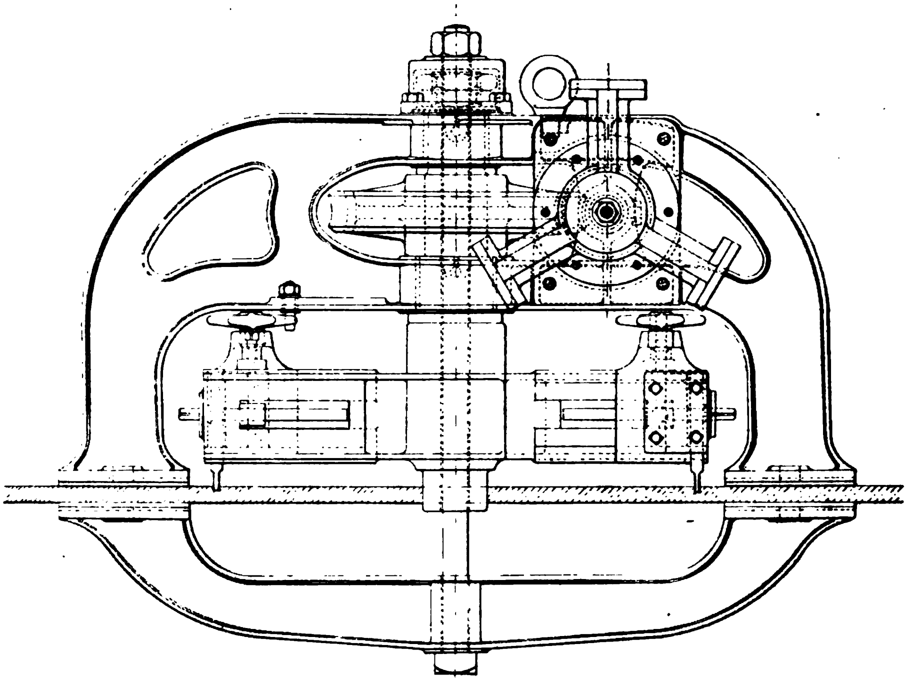
West, Newman Photo.

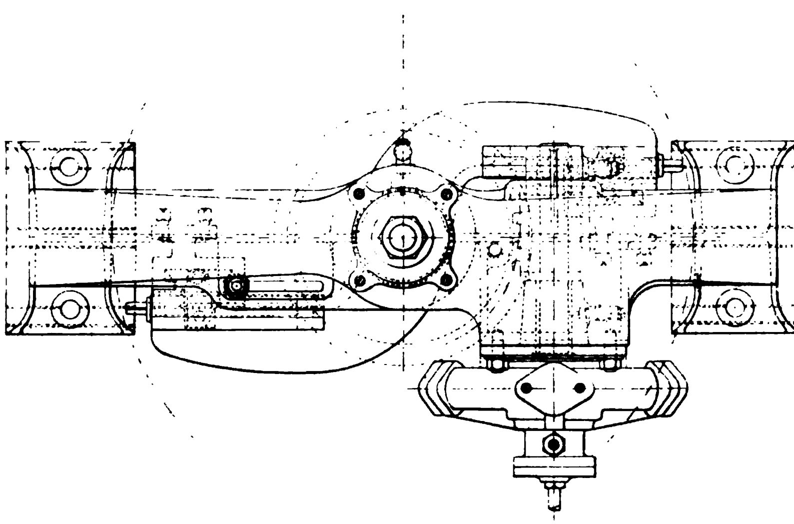
up to 30 inches, in iron or steel. The double radial arm which carries the cutters is driven by a Brotherhood three-cylinder engine through worm gearing. The engine has cylinders 1¾ inches diameter, with a stroke of 2½ inches. The feed is given to the cutters automatically, the star wheels on the feed screw engaging with a stud on the frame at each revolution. The machine is held to its work by means of a tension bolt (passing both through the frame and the plate to be cut) to a light steel bridge bracket on the other side of the plate. The only preparation that is required for fixing the machine is the drilling of a single hole about 3 inches diameter. The manhole cutter may then be fixed in position ready for work. The apparatus may be applied in any position, either on work in course of construction, or on the plates themselves in the yard. The working pressure is 1,500 lbs. per square inch.

HYDRAULIC DRILL AT ST. GOTHARD TUNNEL.

In the construction of the St. Gothard Tunnel, hydraulic power was successfully employed for the purpose of rock-drilling. The Brandt rotary drill was used at the Pfaffensprung Tunnel on that railway, and more recently at the eastern end of the Arlberg Tunnel. The power was obtained from two high-pressure pumps, which were worked by a turbine pumping into an accumulator at a pressure of 1,200 to 1,500 lbs. per square inch. A 1½-inch wrought-iron pipe conveyed the water to the machine. Plates 40 and 41 show the construction of the drill, as explained to the Institution of Mechanical Engineers. The drill M is hollow, and is screwed on to the hollow bar Q, which is attached to the plunger I of the ram O, working in the guide cylinder P. Upon this guide (and in one piece with it) is a spur wheel H driven by the worm J. The whole machine is movable from the horizontal tube N (to which it is attached) by the collar piece F. The stop cock Z in the valve-chest B admits

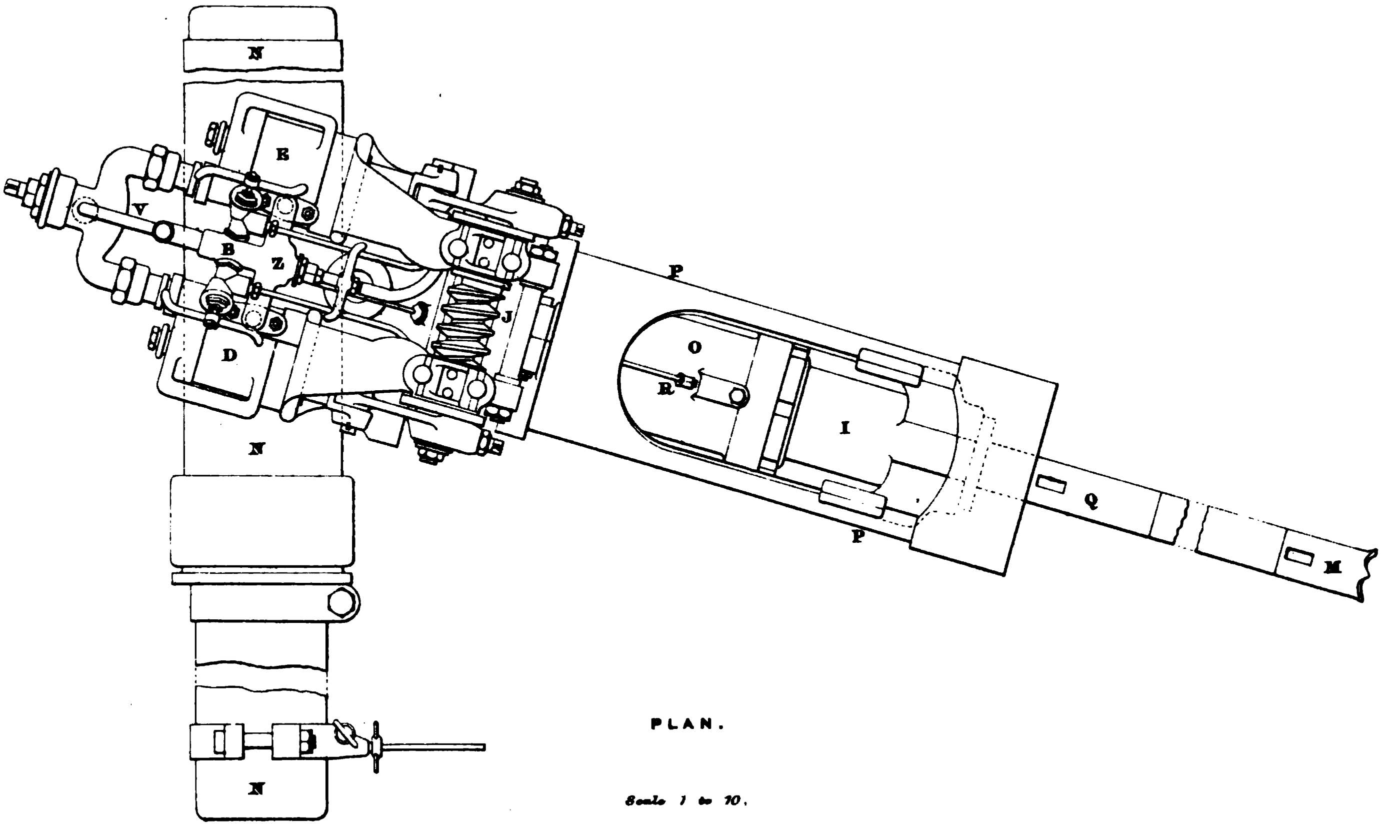
HYDRAULIC MANHOLE CUTTER.





West, Newman Photo.

BRANDT DRILL.

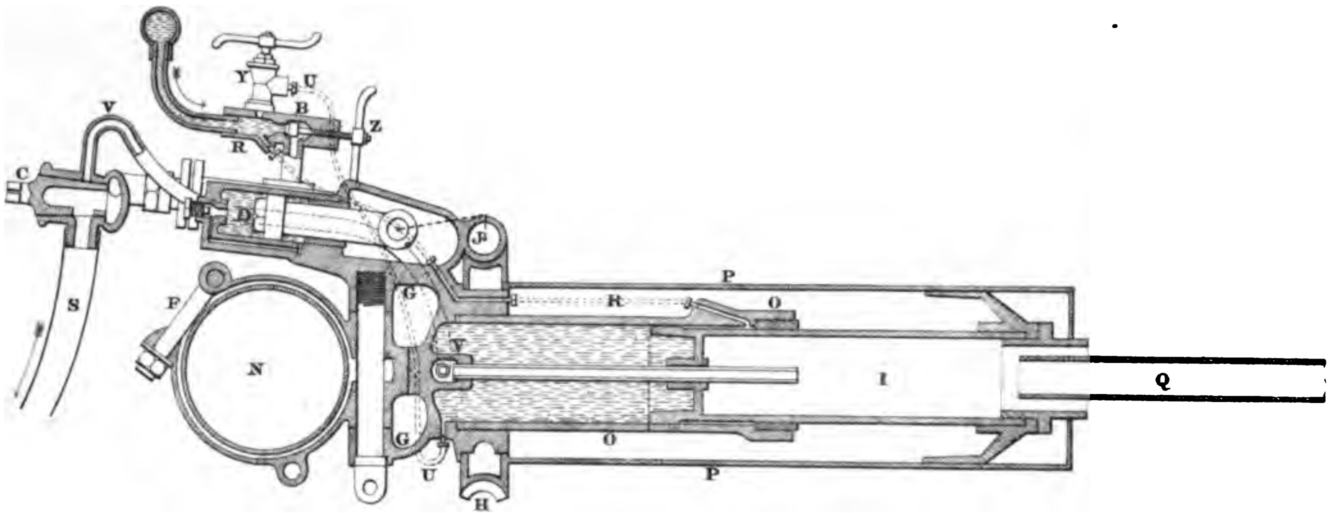


PLAN.

Scale 1 to 10.

Thos Kell & Son Lith.

BRANDT DRILL.

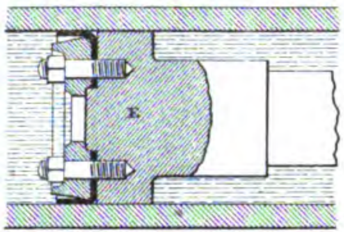


LONGITUDINAL SECTION.

Scale 1 to 10

Thos Kell & Son, Lith.

Fig: 2.



SECTION OF PISTON, ENLARGED.
Scale 1/10th

Fig: 1.

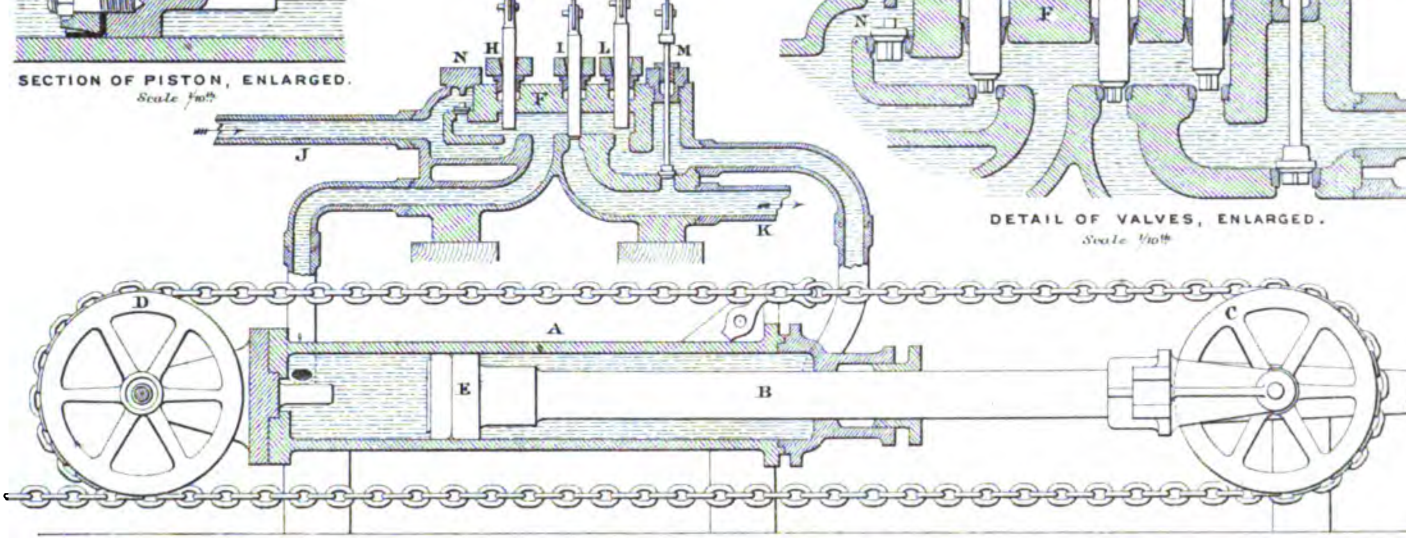
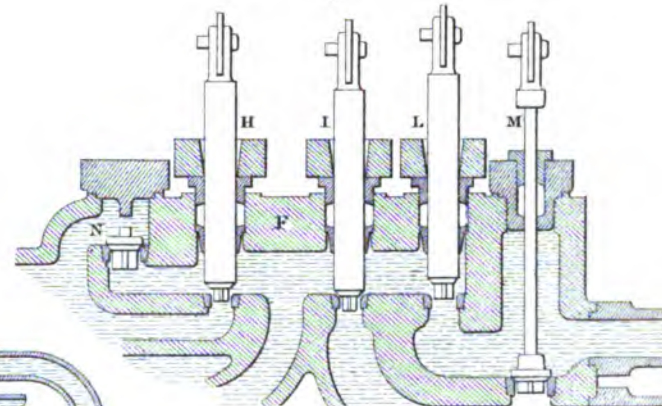


Fig: 3.



DETAIL OF VALVES, ENLARGED.
Scale 1/10th

DOUBLE POWER HYDRAULIC CRANE.
LONGITUDINAL SECTION OF CYLINDER AND VALVES.

Scale 1/20th
Ins. 12 6 0 1 2 3 4 5 Feet

the water into a branch pipe leading to the motors DE (about 13 HP each). These drive the worm J, which rotates the drill, at the rate of from 7 to 10 revolutions per minute. By opening the tap Y the water is admitted through the pipe U to the back of the drill plunger I, thereby pressing the drill against the rock with a force of from 10 to 12 tons. When the tap Y is closed, the water passing through the pipe R drives back the plunger. The extent to which the tap Y is opened regulates the pressure upon the plunger.

The hole can be washed out, to clear it of *débris*, by closing the cock C in the pipe leading from the motors to the escape hose S. The exhaust water from the engines then passes by the pipe V into a pipe in the cylinder O, and is discharged through the hollow plunger and drill into the drill hole.

The supporting pillar N consists of a tube with a plunger fitted into it. By admitting water-pressure into this tube, the plunger head is forced out against the sides of the heading, by which the pillar is set fast. The plunger can be withdrawn by means of a two-way cock. The pillar and drills are carried on a trolley, and are counterbalanced so as to be in equilibrium when the pillar is not fixed.

MOTORS WITH VARIABLE POWER.

In utilising water-pressure, uneconomical results are produced in cases where the work to be done is variable, whilst the water that is consumed by the appliance is invariable. This was recognised by Lord Armstrong at the commencement of his labours in the application of hydraulic power, and he met the difficulty by employing what is known as a "double power"—*i.e.*, by using a combined piston and ram, as shown on Plate 42. Fig. 1 shows the arrangement of cylinder, piston, sheaves, chains, valves, &c., for a double-powered hydraulic crane. Fig. 2 is an enlarged section of the piston, and Fig. 3 gives the details of the valves. A is

the hydraulic cylinder, B the ram, and E the piston. The water from the accumulator enters the valve-chest F through the pipe J, and the inlet valve H. By opening the valve L water is admitted to both sides of the piston, so that the power that is exerted, and the water that is consumed, are due to the annular ring, or the difference between the areas of the ram and piston. In the event of the higher power being required, the valve L is closed, and the valve M is opened, whereupon, whilst the full area of the piston receives the pressure, the other side (or annular ring) is open to the exhaust K. For lowering a load the valves H and M are closed, and the outlet valve I is opened, which allows the water to escape from the cylinder into the exhaust pipe K. The valve L is also open to allow the water to follow up the piston in the inward stroke.

The late Mr. Michael Scott suggested the using of the waste water from cranes, by returning it through the pumps which charge the accumulator. He proposed an accumulator so loaded that the ram ascends with the pressure due to the descent of the lightest load. Two similar forms of apparatus are provided, each consisting of a hydraulic cylinder, in which works a piston, with a weight on the top of its rod. The waste water from the hydraulic cranes and lifts (being under the pressure due to the weights of their descending rams) is admitted below the piston in one of these cylinders, and the piston rises until it reaches the top of the stroke, when it opens communication with the other cylinder, the piston in which also rises. Communication in the meantime has been opened between the top and bottom of the first cylinder, and at the same time between the cylinder and the high-pressure main supplying the cranes and lifts. Owing to the difference of area for the water to act upon on the upper and lower sides of the piston, the pressure required to raise the piston is less than the pressure under which the water is forced out of the cylinder when the weight descends.

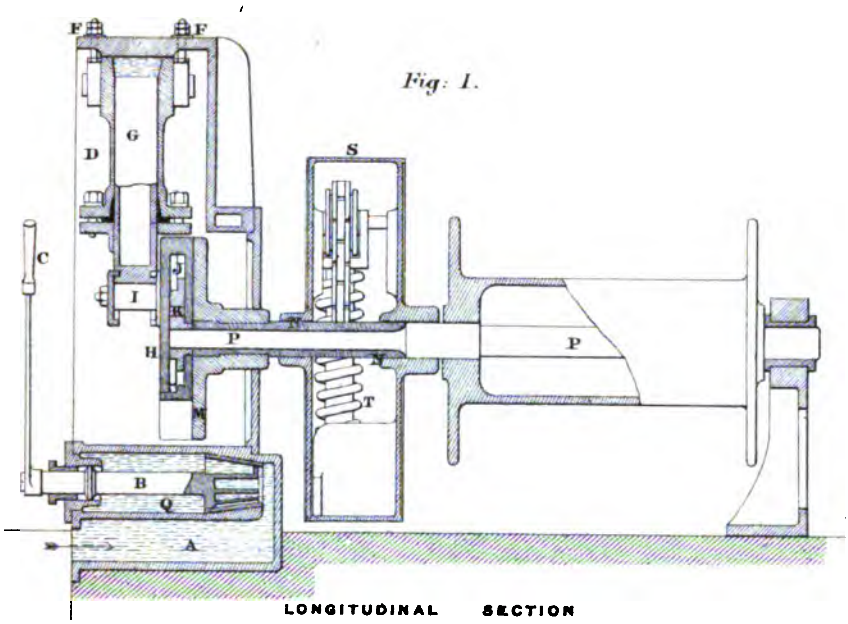
Mr. Robert Mills has devised a crane to meet the case of

variable loads. The slewing cylinders which turn the crane (by chains passing round a drum fixed on the crane post) are utilised for the further purpose of aiding in lifting the weight. Four cylinders were to be employed, namely, the lifting cylinder, two turning cylinders (these three having rams), and a fourth, called the lowering cylinder. The latter has a piston, the rod of which is attached to the pulley-frame on the head of the ram of the lifting cylinder. The turning-chain passes round the turning-drum over the sheaves of the turning-rams as usual, but the ends are attached to the lifting sheave frame, so that the turning-rams can be used as auxiliaries to the lifting-ram, or independently of it, to lift light loads. In lifting a load by means of the turning cylinders, the water is admitted to both turning cylinders, and if the load is not too heavy to be lifted by these cylinders, the lifting sheave frames (with the ram and piston of the lifting and lowering cylinders) will be moved. The lifting cylinder and front end of the lowering cylinder will draw water by suction from the exhaust pipes. The water from the back of the piston of the lowering cylinder is discharged into the front end of the lowering cylinder (or into the lifting cylinder) along with the water from the exhaust. If the power of the turning cylinder is insufficient to raise the load, then the water is admitted to the front end of the lowering cylinder to assist in lifting, when, if the load is not too heavy, the lifting sheave frame with the ram and piston of the lifting and lowering cylinders will be moved. The back of the lowering cylinder discharges its water into the lifting cylinder, and the deficiency, if any, in the lifting cylinder is made up from the exhaust as before. Should the turning and lowering cylinders be of insufficient power to lift the load, the water is admitted to the lifting cylinder, but is shut off from the lowering cylinder. If the power that is now applied is sufficient to lift the load, the front end of the lowering cylinder will draw water from the exhaust. The back end of the lowering cylinder will then discharge its water (against the pressure) into the lifting

cylinder. Should the power applied be insufficient to lift the load, the pressure will be readmitted to the front of the lowering cylinder, which will now act in conjunction with the turning and lifting cylinders. The back end of the lowering cylinder (as before) discharges its water, against the pressure, into the lifting cylinder. Should the power applied as last described be insufficient to lift the load, then the water from the back end of the lowering cylinder is allowed to discharge into the exhaust, when the full power of the crane will be exerted. When the crane is lowering the load, the water from the lifting cylinder is allowed to discharge itself into the exhaust, when the load (if heavy enough) will force the water from the front of the lowering cylinder into the pressure pipes. If the load is insufficient to lower in this manner, then the pressure is admitted to the back of the lowering cylinder, and the water from the front of that cylinder is discharged into the pressure pipe. The water from the lifting cylinder is also discharged into the exhaust pipes.

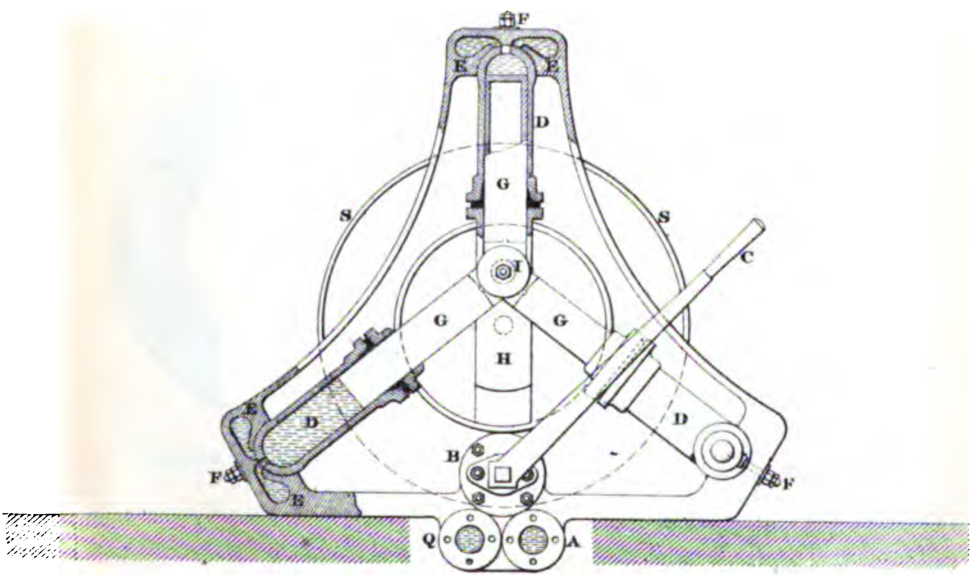
Mr. John Hastie adjusts the consumption of power in water-pressure rotary engines by varying the stroke of the piston. He accomplishes this by arranging the crank-pin so that it has a variable throw, and he also does the same by employing a link, as in the expansion gear of a steam-engine. An example of it as applied to a low-pressure hoist is shown on Plates 43 and 44, which are taken from the *Proceedings of the Institution of Mechanical Engineers.* A is the inlet pipe, from which water is admitted through the cock B, under the control of the handle C. When the handle is in its extreme positions, the cock B acts as a reversing valve, and when the lever is vertical the cock acts as a break, owing to both parts of the cylinders communicating with the exhaust Q, the pipe of which contains water enough to fill the three cylinders D. Each cylinder alternately forces water into, or draws water from, the exhaust pipe Q. Two communication-passages are formed in the framing between the cock B and each of the cylinders D, the termination of these passages being at E

Fig: 1.



LONGITUDINAL SECTION

Fig: 2.



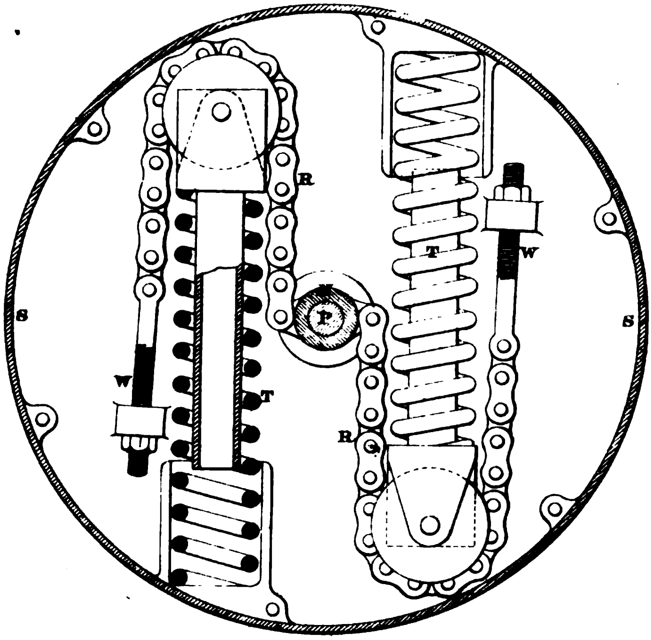
END ELEVATION.

Scale 1/12 th

Ins. 12   9   6   3   0   1   2   3   4 Feet

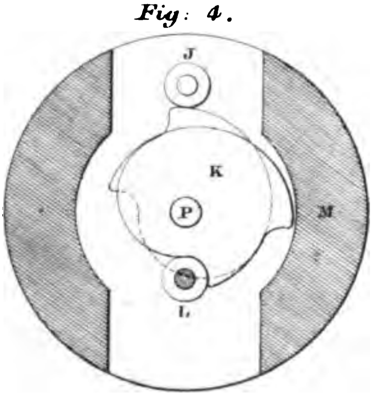
Thos Kell & Son, Lith.

Fig: 3.



SPRING CASE.

Fig: 4.



DOUBLE CAM AND ROLLERS

Fig: 5.

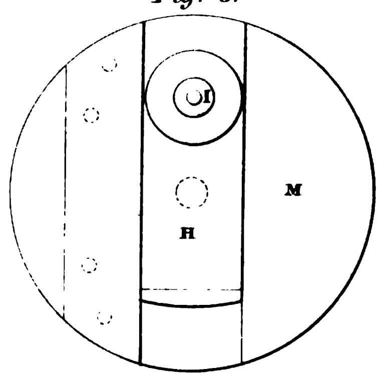
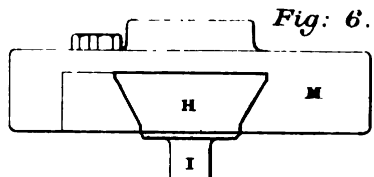


Fig: 6.



CRANK-PIN SLIDE

Scale 1/8th

Thos Kell & Son, Lith.

(Fig. 2). The oscillation of the ends of the cylinders serves instead of valves to admit the water. By the eye-bolts F (Fig. 2) the cylinders are held and adjusted, and working in them are trunnions that are cast on the cylinder ends. The rams G act direct on the crank-pin I, formed on a sliding frame H, and by it the stroke can be adjusted. The double cam K (Fig. 4) works between two plates, forming the frame H (Figs. 1, 2, 5, and 6). To the outer plate are attached two small steel rollers, L and J, rolling on the outer and inner halves of the cam. Figs. 5 and 6 show the action of the frame H. This slides within a disc M, which is keyed on the hollow shaft N (Fig. 1). The cam K is keyed on the barrel shaft P, Fig. 1 (the working shaft of the hoist), passing through the hollow shaft N. On the latter are formed two wings, to which are attached chains, R (Fig. 3). To the barrel shaft P is keyed the spring case S, containing the two springs TT. When the engine is at rest, and without load on it (the crank-pin being then on its shortest throw), the springs TT have pressure put on them by the screws WW only sufficient to hold the roller J against the nearest end of the curve of the inner half of the cam. The pressure also prevents any change in the position of the crank-pin, should the engine be running without any load. When a weight has to be lifted, the hollow shaft N at first turns and winds up the chains, compressing the springs, until their resistance balances the pressure put upon them by the weight, whereupon the spring-box S begins to revolve, carrying round with it the shaft P, thus raising the weight. The relative positions of the two shafts have now been altered from those shown in Fig. 3, the rollers having moved along the curves of the cam, by which the position of the sliding frame has been shifted, and the crank-pin has been given an increased stroke proportional to the load that is being lifted. On the weight being removed, the springs open, causing the roller L to bring the crank-pin to its shortest throw. The variation of the stroke is thus automatic, and causes the consumption of water to

vary with the work that is done, instead of the consumption being invariable, as is the case with the ordinary rotative engine.

When this arrangement is applied to the high pressures from accumulators, the springs are not employed, but water rams are substituted which are connected, through the centre of the barrel shaft P, with the supply pipe. The chains in this case are wound on cams, instead of on the shaft; greater power is thus required to force back the rams in proportion as the chains act at an increasing distance from the centre of the shaft. Experiments have been made with one of these engines, which was applied to work a hoist with a 22-foot lift, and with a water-pressure of 80 lbs. to the square inch. The results are given in the following table :—

Weight lifted in pounds . .	Chain only.	427	633	745	857	969	1081	1193
Water used in gallons . . .	7½	10	14	16	17	20	21	22

Whilst recognising the soundness of the principle of endeavouring to adjust the consumption of water to the work that is actually performed, some of the ingenious arrangements referred to involve the sacrifice of simplicity, and the man in charge of the machine cannot be depended upon to employ them. In machinery for working hoists, where the weights to be lifted are great, and where the variation between the heaviest load and the lightest load is considerable, it is an advantage to make arrangements for economising the water, and no objectionable complications are involved, as is the case in smaller and lighter appliances.

For heavy cranes also variable power should be applied, unless in situations where the crane is very seldom used. Then the interest on the additional outlay of capital is not recouped by any saving of water. In small cranes which are constantly worked, and where great rapidity is required, the

double power is seldom of service. The men will often omit to work with the low power, as they find they can get so much more speed out of the higher power, when lifting light loads. The cost of the water thus wasted is comparatively so small that it does not pay to complicate the machinery in order to avoid the waste, especially as the addition of variable powers involves more attention on the part of the men, and more wear and tear to the machine. In working capstans it is found that, in hauling trucks, the men often prefer to put on the full pressure at the outset, to give a quick start to the load, and then to let the load run some distance, instead of using low power and keeping it on for a longer distance. It is found that the men are able to do the work better where they can start the waggons quickly, and with a good speed, than they can by using a lower power, and by keeping it on more continuously through the distance.

HYDRAULIC MACHINERY ON BOARD SHIP.

Hydraulic power is now being applied to perform the deck work on board the larger steamships, instead of the steam appliances which were previously used. In discharging a ship's cargo, the expedition afforded in all large docks, by the employment of hydraulic cranes and other appliances, have not until quite recently been met with corresponding facilities on board ship.

On board steamships the accumulator can be dispensed with, as the power required to work hydraulic apparatus under these circumstances is generally produced, and communicated direct to the machine, by motors which are capable of working at very high speeds, and of developing in a small compass a large amount of energy.

Direct-acting cylinders, working upon the single crank, have been applied by Sir William Armstrong, Mitchell & Co., to ship-capstans up to 5 tons power. In these the bed-

plate is fixed, as it would be too unwieldy to use in the form of the turn-over arrangement already described for docks and yards. The capstan-head is in some instances arranged with two diameters; the larger being for the lighter power, and the smaller for the heaviest strain upon a hawser. The capstan-head is also provided with handspikes and rack, so that, if desired, it can be worked by hand as an ordinary capstan. A separate hydraulic engine (usually with three cylinders) is attached to the masonry, and, by means of gearing, the power is conveyed from it to the capstan, the shaft of which is firmly fixed to the foundation, the upper part being carried by cast-iron framework.

The greatest power that has hitherto been given to ships' capstans is represented by a pull of 11 tons on the hawser, although, as a rule, a 5-ton capstan is found sufficient. A variation of power may be given either by means of gearing, or by applying a triple-power hydraulic-capstan engine either direct to the capstan or through gearing. In practice, however, it is generally found that the saving of power effected is not commensurate with the complication involved.

Mr. A. Betts Brown has devoted much skill and attention to this branch of hydraulic machinery. In papers communicated to the Institution of Mechanical Engineers, and to the Institution of Naval Architects, he has given data as to the employment of hydraulic apparatus of various kinds on board the "Quetta" (of the British India Steamship Company). The prime mover for the hydraulic machines on this ship consists of a pair of compound surface-condensing pumping-engines of 100 indicated horse-power, independent of the ship's engines. The average speed is 40 revolutions per minute (never exceeding 70 revolutions). The engines are connected with pumps attached to a steam accumulator, with a pressure of steam from the steam-pipe of 80 lbs. to the square inch. This pressure acts on a steam piston and water ram, having areas in the proportion of 10 to 1. A pressure of 800 lbs. to the square inch is thus produced in the hydraulic system.

On board the "Quetta" two single lifts are placed at the extreme hatches, and two pairs at the main hatches. These consist of long cylinders (passing through the upper and main decks), which contain lifting rams, each having three sheaves, a corresponding number being fixed in the upper deck. By this arrangement a lift of 70 feet is obtained. The weight lifted by each is 30 cwt., but, by connecting a pair together, 3 tons can be raised. The speed of lifting averages 5 feet per second, and to prevent accidents at this high speed (in the event of the cargo breaking away) an automatic arrangement is provided. An appliance called the "Hydraulic Derrick Topping Gear" is attached to the mast. It consists of a cylinder having a ram, with one sheave carried at its end, working downwards, so that its weight may tend to balance the weight of the derrick. The fast end of the chain is held by a clip; it passes round the sheave on the ram, thence over a swivel-pulley on the mast, and lays hold of the end of the derrick. A small slide-valve is placed close to the hoist and hatch, the admission port of which is connected to the cylinder by a small pipe up the mast. The hoists are sometimes arranged in pairs (where there are two derricks) with a communicating pipe and valve.

The positions of the fore and aft hatches of this ship with reference to the masts were such that while the derricks were set to plumb the hatches, they would not reach over the side of the ship on swinging round. This difficulty was overcome by attaching to the mast a small hydraulic cylinder, with its ram working downwards, carrying a sheave round which the derrick-chain passed. From this cylinder (which is placed some 20 feet up the mast) a small pipe is led to a valve placed close to the hatchway. The man in charge works the hoist lever with his right hand, and with his left the derrick lever.

Hydraulic power is also employed to work the steering-gear of ships. It is necessary that the power applied should increase in proportion to the angle at which the rudder is moved

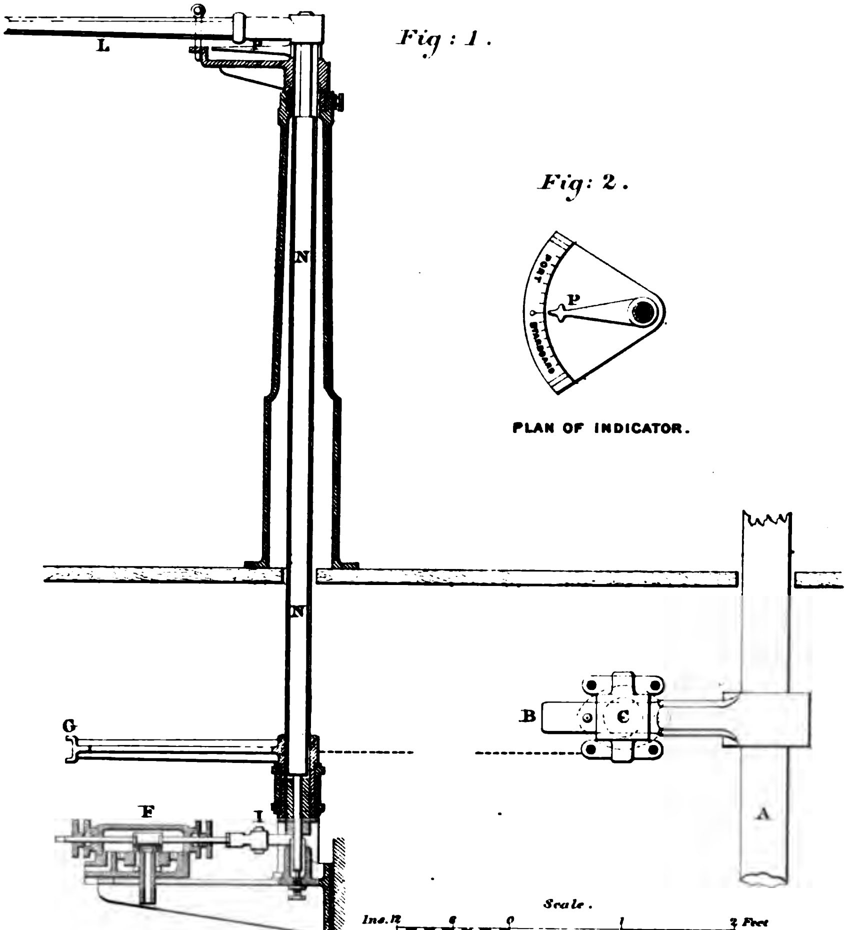
over, and that the machinery should yield under any excessive strain, so as to allow the rudder to fly amidships, but to return after the strain has passed away. The valve for controlling the steering-gear should be placed where it can be worked under the eye of the officer of the watch. Mr. Betts Brown has arranged hydraulic steering-gear, as shown on Plate 45.

A is the rudder post, B is the main tiller, which is keyed to the post. The end of the tiller is cylindrical, so as to allow the sliding-block C to slide radially upon it. This block is connected by trunnions to hydraulic rams, working in a cylinder, from which separate pipes are carried to the admission ports in the slide-valve F, which is placed at the bridge. When the main tiller is moved in either direction towards its extreme position, the sliding-block runs out upon it, and the proportionate extent of motion in the effective leverage of the rams is increased until the power over the rudder becomes doubled, when the rudder is hard over at 45°, on either side of the midships position. A wire cord passes from the rams to a quadrant G, by which the motion of the rudder-post is communicated to the quadrant. This forms an automatic cut-off by the slide-valve F, and serves also as a deck indicator. The steering valve F is shown in section to a larger scale in Fig. 3. It is three-ported, the two end-ports JJ leading through the pipes to the hydraulic cylinders astern; the centre port being the exhaust. The water enters the valve-chest by the port H. Relief-valves KK provide for the shocks caused by a heavy sea striking the rudder. The steering tiller L (Fig. 1) is fixed upon the shaft N, which passes down from the bridge to the valve F on the maindeck, and terminates in a crank at the bottom. This crank works one end of a floating lever I (Fig. 1) by a pin and connecting-link. The other end is attached by a similar connecting-link to a crank-pin in the quadrant G. To the middle of this lever I is joined the slide-valve spindle. If the valve is opened by moving the steering tiller L and the lever I, water is at once

HYDRAULIC STEERING GEAR.

Fig: 1.

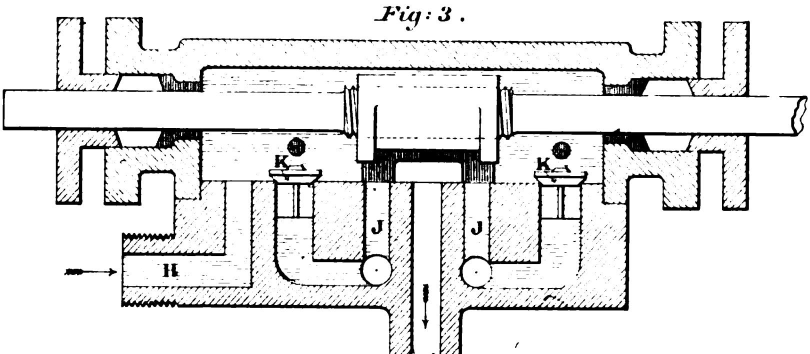
Fig: 2.



PLAN OF INDICATOR.

VERTICAL SECTION.

Fig: 3.



SLIDE VALVE.

Thos Fell & Son Lith

HYDRAULIC REVERSING GEAR.

Fig: 1.

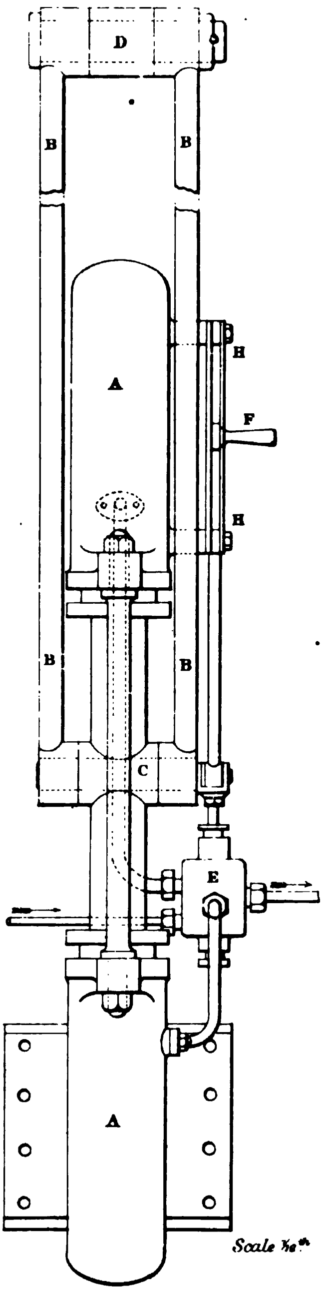
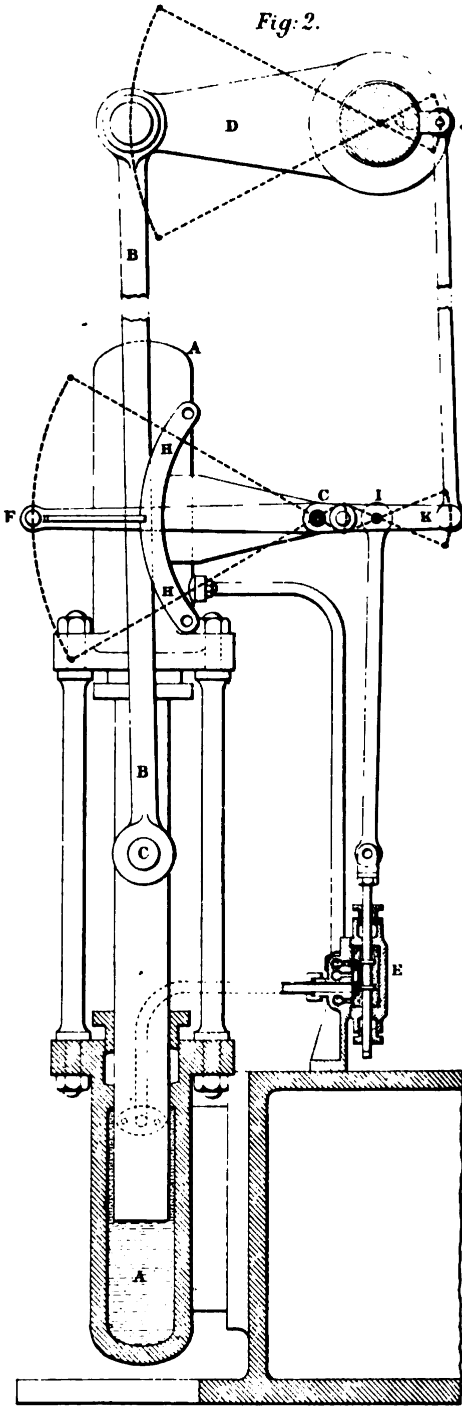


Fig: 2.



Scale.

Inches 12 6 0 1 2 3 4 Feet

Thos Kell & Son Lith

admitted to one of the steering cylinders and is exhausted from the other, causing the ram to move the rudder. But as the quadrant G receives motion from the rams by the wire cord, and, therefore, moves through precisely the same angles as the rudder, its crank-pin is carried in the opposite direction to the crank on the shaft N, and the slide-valve is by that means shut. Any further movement of the steering tiller L will produce further motion in the rams, with a corresponding counteracting motion of the quadrant. The slide-valve is also opened immediately by the quadrant whenever the rudder is driven amidships by a heavy sea, and thus a double relief is afforded to the water. The quadrant closes the valve again on the rudder returning to the position from which it was disturbed. The shaft N of the steering tiller has a tubular casing which is fixed to the quadrant below, and is carried to the top of the steering pedestal with a pointer P (keyed on it), to indicate by a graduated arc the position of the rudder, as shown by Fig. 2. In the steering-gear for ships of the "Quetta" type, large relief valves are placed on each cylinder. Their exit pipes cross over to each other, so that when a sea strikes the rudder, the water is forced out of the cylinder acting against it into the opposite one. These valves are set to blow off when the rudder is subjected to over one-fifth of its breaking strain.

Plate 46 shows Mr. Betts Brown's "hydraulic reversing gear" as applied to the "Mikado" (3,000 tons). The apparatus consists of two hydraulic single-cylinder engines AA (Figs. 1 and 2), with rams 4¾ inches diameter and 19-inch stroke, coupled together and working in opposite directions. They are connected by slide-rods B, from the boss C to the weight-shaft lever D. Water is admitted to either of the cylinders by opening the slide-valve E by the handle F, which is centred at G, and has a detent rod and quadrant H. The reversing handle F is connected to one end of the short double lever K, the other end of which is moved by a connecting-rod from a stud point J on the back of the weight-

shaft of the main engines. The slide-valve spindle is attached to the double lever K at an intermediate point. When water is admitted to the lower cylinder by a downward movement of the reversing handle, the slide-valve is raised, and the hydraulic rams are moved in an upward direction, carrying with them the weight-shaft lever D, and reversing the engines. By the same movement the stud point J upon the weight-shaft is lowered, and closes the valve again, so that the two rams are held fast in whatever position they may be placed. This counteracting cut-off enables the engineer at once to place the reversing links of the main engines at any degree of expansion, and to hold them there, by simply moving the reversing lever into the desired position in its quadrant. The rams follow at once into that position and stop there.

HYDRAULIC POINTS AND CROSSINGS.

Hydraulic power has been successfully applied to apparatus for working railway points and signals, water under pressure being employed in lieu of rods. MM. Bianchi and Servattaz have perfected apparatus for this purpose, which has been introduced on various lines of railway. The points are worked by two plungers, placed in communication with water under pressure on one side, and with an exhaust reservoir on the other, so that the plungers move right or left, and so give motion to the points. The apparatus is fixed between the rails, and is connected by two lines of pipes to the pressure and exhaust. Each point can be locked by cams mounted on the ends of a rod that can be made to rotate by a crank actuated by the plungers. The liquid employed is a mixture of water and glycerine. Power is obtained from a small accumulator charged by a hand pump at intervals, the liquid being drawn from the exhaust reservoir already referred to. The system admits of application to

other purposes in connection with railways, such as to locking level crossing gates, turntables, traversers, &c.

HYDRAULIC PILE DRIVER.

In the construction of the Alexandra Docks, Hull, Messrs. Lucas & Aird employed a hydraulic hoisting machine for the purpose of driving piles. The machine thus utilised consisted of an ordinary grain hoist with the working chain-drum removed. The monkey chain was worked direct from a ram $7\frac{5}{8}$ inches diameter and 3-feet stroke. A recessed chain sheave, with grip gear fitted to it, acted as a brake, and prevented the chain which leads to the monkey from slackening. Intermediate sheaves guided the chain from the ram to the monkey. Another sheave took the chain (after it had passed over the ordinary ram sheave), and to the shaft of it a brake wheel was keyed, which was used to prevent the chain from slackening out in the direction of the balance weight. The monkey chain was led over the top of the pile engine in the usual manner.

Were it only required to work the monkey at a stated height, the brake appliances and the balance weight would be unnecessary, as the ram would do this with the end of the chain made fast as usual. Where, however, the height at which the monkey had to be worked varied through the level of the ground from 40 feet to 45 feet, it could not be done without some such arrangement for shortening up, or letting out, the chain. This was also required for lifting the pile from the ground for fixing.

Knuckle-jointed pipes connected the machine with the hydraulic main, and could be doubled up or extended, as the machine moved in either direction.

The action of the machine will perhaps be best shown by describing the lifting of a pile. The chain is attached to one end of a pile on the ground. The brake is applied to prevent

any movement at this end of the chain. The ram is set in motion, and having a 3-feet stroke, with multiplying power 4 to 1, its pullies lift the pile about 12 feet. The grip gear is then applied to prevent the pile from lowering, as the ram recedes. The brake is then loosened, and the ram is allowed to recede, the slack chain being taken up by the balance weight which lowers. When the ram is fully back the brake is again applied, and the pressure is turned on the ram. The grip gear is loosened, and another similar lift is taken with the pile. In driving the pile, the monkey is lifted to the required height in a similar manner to that described. The brake is then applied, and is kept constantly on, until it is desired to work the monkey at a lesser height. The ram then works the monkey at whatever stroke is required. When the monkey has to be lowered (as the pile is being driven) the grip gear is applied when the ram is back, the brake is loosened, and the ram, being set in motion, lifts the balance weight, taking the chain from this end. When a sufficient quantity of chain is obtained, the brake is again applied and the grip gear loosened. Then as the ram recedes the monkey is lowered.

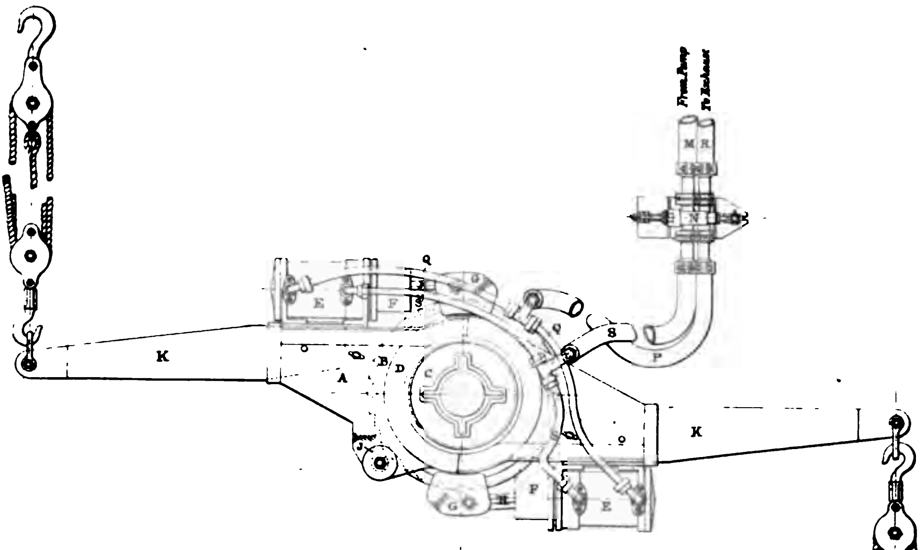
This machine was found to work very smoothly, and it fully answered the purpose for which it was employed. It gave fourteen blows per minute through an 8-feet drop, with a monkey weighing one ton. This rate of working compared favourably with other pile drivers which were at work at these docks, as the maximum number of blows per minute with a similar drop was only eleven.

HYDRAULIC PILE SCREWING APPARATUS.

An ingenious application of hydraulic power is that of a pile screwing apparatus which has been patented by Messrs. Wrightson & Clark, and is illustrated by Plate 47.

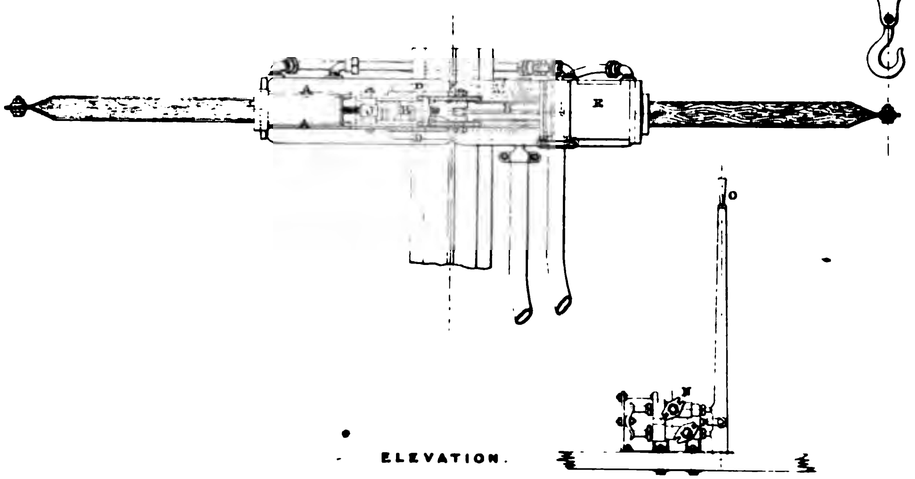
The frame of this machine consists of two wrought-iron

WRIGHTSON & CLARK'S HYDRAULIC SCREWING APPARATUS.



PLAN.

Scale, 3/8" = 1 Foot



ELEVATION.

West, Newman Photo

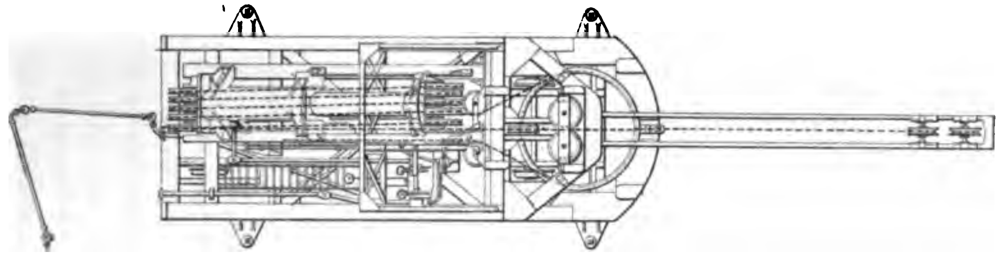
plates marked A, between which is inserted a cast-steel ratchet wheel B, about 2 feet 7⅝ inches diameter, over the teeth, and having 32 teeth in its circumference. A boss C, cast on each side of the ratchet wheel, passes through steel angle rings, D, secured to each side of the wrought-iron frame, and in which the ratchet wheel revolves. The boss C of the ratchet is cored out to suit either piles of segmental iron, or to receive the driver, which may be bolted to the top of the piles, when they are of large size, and varying sections. At each side of the frame, and at opposite ends, are two hydraulic cylinders, E, with trunk pistons, F, which latter are connected to the ratchet and the frame G, in which the ratchet works, by a cast-steel knuckle-jointed connecting rod H. The stroke of the piston is a little more than 2 pitches of the teeth in the ratchet wheel, and, therefore, requires about sixteen strokes to make a revolution of the pile. The ratchet wheel is prevented from slipping back on the return motion of the piston by a pawl J. At the extreme ends of the frame are inserted arms, K, made of wood plated with iron, and at the ends of these levers are shackles to receive hooks of rope tackles, which are secured to something rigid near the apparatus and which form the resistance to the hydraulic cylinders. The power is obtained from a set of hydraulic pumps capable of working to 600 lbs. per square inch, and having four 4-inch diameter rams, 6 inches stroke. In the framing for these pumps is a small tank to receive the return water from the machine and from which the rams take their supply. The pumps are driven by a belt from a portable engine placed in any convenient position. From the pumps the water is conveyed by the wrought-iron pressure pipe M, to the working valve N, which regulates the supply and the exhaust to and from the machine. The valve is actuated by the hand lever O. The pressure is conveyed to the back end of the hydraulic cylinders by an india-rubber hose pipe, P, and by copper pipes, Q, by which also the discharge water is carried back to the valve and pumps, by the waste water pipe R connected to the waste tank. There is also a

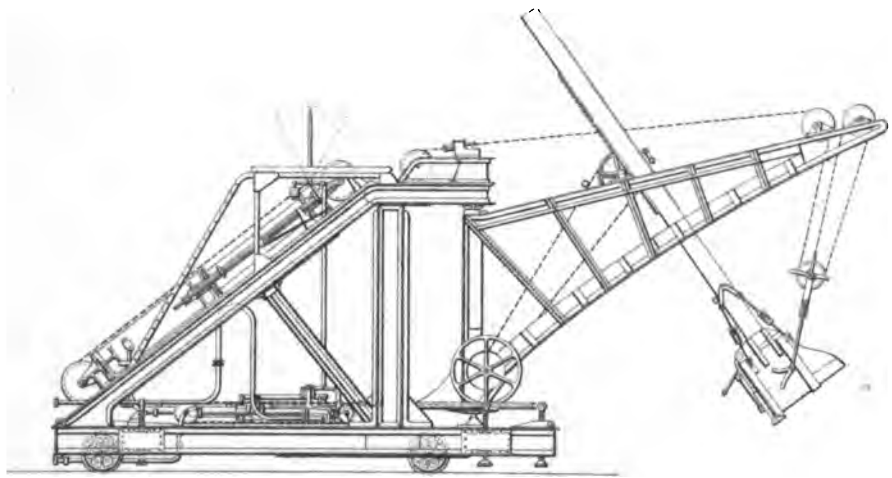
constant pressure connection, S, between the working valve and the front end of each cylinder, by which the pistons receive their power for the backward stroke. But few men are required to work this machine compared with the ordinary mode of screwing by capstan head and hand winches, and piles can be screwed in much less space. The power is regularly and uniformly applied, and consequently the pile is accurately driven without any tendency to drag the pile out of position, so that, except in the case of heavy piles, very little guiding is necessary. There is no fleeting over of ropes as is usual in the case of screwing by winches of the ordinary type, so that a much more continuous motion is given to the pile, which is important, especially when screwing in sand or silty ground, whilst its action is quicker than that of a capstan driven by ordinary steam winches. It is as easily applied to battered as to plumb piles, and when either of these are inclined to deviate from their true line they can quickly be thrown into any other position in order that they may be worked back again to their true place.

HYDRAULIC EXCAVATOR.

During the execution of the works at the new Alexandra Dock, Hull, it occurred to Mr. John Aird to excavate the material by utilising the water-pressure in the mains that were laid for working the permanent hydraulic machinery of the dock. A machine to accomplish this was accordingly constructed as shown by Plate 48. The circumstances were favourable to the utilisation of hydraulic power, inasmuch as it was within easy reach of the machines to which it had to be applied. The "hydraulic navvies" (as they were called) were, however, at times working at a distance of half a mile from the source of the power, and as there were several cranes, hoists, and other machines which abstracted power at various intermediate points, it was considered that

HYDRAULIC EXCAVATOR.





Thoˢ Kell & Son, Lith.

the effective pressure at the "navvies" was about 700 lbs. per square inch, although the accumulator pressure was 750.

The machines are fitted with main rams, E, 14 inches diameter and 4 feet 6 inches stroke. The chain for drawing one scoop through the excavation, works over sheaves, F, the multiplying power being 10 to 1. The chain at the scoop end is worked over sheaves, G, twofold, thus giving a ratio of 5 to 1 in speed and stroke on the ram and bucket. The range generally required for the scoop was from 15 to 18 feet. In ordinary working about 3 feet 6 inches stroke was required on the ram. There are two smaller rams H (to slew the main jib) 4½ inches diameter, and 4 feet 2 inches stroke, which are fixed horizontally on the top of the bottom framing. The chains from these are attached to opposite sides of the circular platform at the bottom of the jib.

The machines are moved backward and forward by means of a hydraulic cylinder J, 3¼ inches diameter, fitted with a piston. The piston-rod is attached to a rocking lever K, about 2 feet 6 inches long, which is centred on the leading axle. This lever is fitted with two catches, reversed, which gear into a double reversed toothed ratchet-wheel M, on the same axle L. The cylinder is arranged so that the pressure can be applied to either side of the piston; therefore, by putting either one or other of the catches into gear, the machine is moved backward or forward. The stroke of the piston is 10 inches, and the ratchet gearing is so arranged that the machines travel about 4 inches each stroke.

The machine being set to work in a cutting (say) from 15 to 18 feet deep, the scoop is drawn up by the main ram through the "face" of the excavation, taking a cut from 4 inches to 6 inches thick, which is just sufficient to fill it by the time it reaches the top. The jib is then slewed round (by the 4½-inch horizontal rams), when the scoop is brought directly over the waggons on either side. The catch which holds the door at the bottom of the scoop is then freed, and the load is discharged into the waggon. The jib is then

slewed the reverse way, and the scoop is lowered, by exhausting the water in the main cylinder. The scoop weighs about 25 cwt., and has a capacity of $1\frac{1}{2}$ cube yard, making a total dead load of about $3\frac{1}{4}$ tons, independent of the resistance due to the scoop cutting through the material.

The hydraulic pipes close to the machine were in 9-feet lengths, fitted with knuckle joints, which admitted of their being so connected to the main pipes that they could be doubled up at starting, and could be extended as the machine advanced for a distance of about 18 feet, before additional pipes were required for the main. When this distance had been reached, the knuckle-jointed lengths were again brought forward and doubled up.

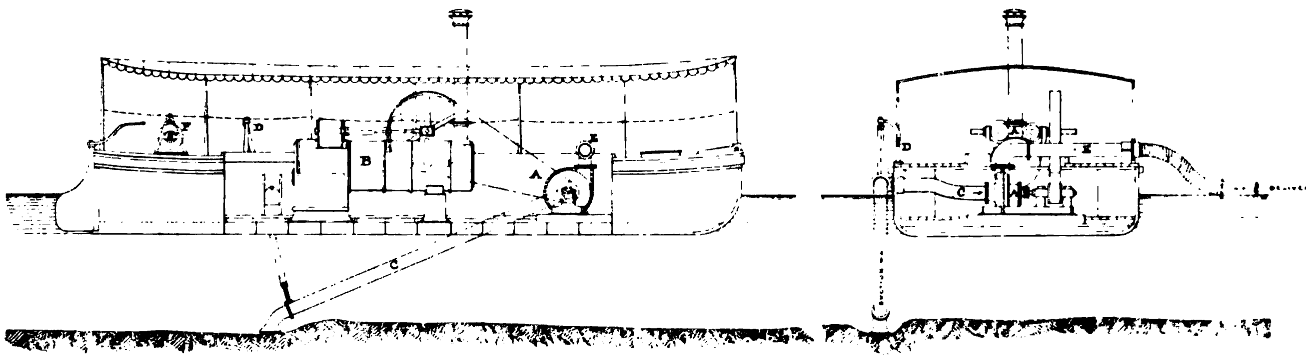
The greatest quantity of material that one of these machines excavated in a day was about 750 cube yards. The circumstances, however, under which they were worked were far from favourable, as the material was of a soft slimy nature, and caused difficulty and loss of time in keeping the machines in a level position. Under more favourable circumstances, these machines were considered to be capable of excavating 1,000 cube yards per day each.

It was found that the "hydraulic navvy" had an advantage over the "steam navvy" owing to there being fewer wearing parts. The action of the working parts was also much smoother, by which the vibration was reduced, and fewer repairs were necessary. A saving resulted, not only in the cost of repairs, but also in the time for doing them.

BALL'S PUMP DREDGER.

A system of dredging by pumping has been employed with success at various places. Sand and gravel passing through ordinary pumps destroy them rapidly and interfere with their working, so that the machinery is continually being stopped

BALL PUMP DREDGER.



and under repairs, consequently dredging by pumping could previously only be employed in dealing with light mud and fine sand.

The Ball pumps are of a design distinct from that of ordinary centrifugal pumps, the aim being to allow big stones to pass without damaging the pump. Special materials and arrangements are employed in their construction to prevent the destructive wear which arises when rapidly revolving parts running against fixed parts are fed with masses of material containing sharp grit.

Plate 49 shows a general arrangement of a Ball suction dredger as is used for river and harbour work. A is a pump, driven by an ordinary semi-portable engine B, and running at about 500 to 600 revolutions per minute. C is the suction pipe with a nozzle at the end, which is sometimes filled with a grating to limit the size of the stones that are to pass. The suction pipe is raised or lowered by means of a chain which is worked from a davit D. E is the delivery pipe through which the spoil is conveyed to the point of discharge. This can be carried by timber floats or by other suitable means. F is the winch which is used for hauling the vessel about while the dredger is at work.

The pumps receive the material by the centre and it is brought into the shell of the pump by a duct in the casting which describes a spiral, so that when the stones and gravel enter the pump, their motion, which was parallel to the shaft, has been transformed into a rotary one, so that the material is already running in the same direction as the blades of the inner fan, the result being that its motion is gradually accelerated by the fan blades, and it, therefore, issues tangentially from the pump. The height to which the material will ascend varies with the nature of what is dredged. The large stones do not give the most trouble, the thick clayey gravels being the most difficult to deal with.

Where weeds have to be pumped a movable valve in a Y piece or breech is employed, by which the material is sucked

alternately through one arm and the other, each being supplied with a suction pipe and nozzle. As soon as one nozzle gets choked the suction is diverted to the other, and the choked one is lifted to the surface and the weeds are removed by an iron claw. Another means of removing material is by employing the pumps to deliver a high-pressure jet into the suction pipe of the dredger, by which an ascending motion of the mixture is caused, and thereby a vacuum is produced at the end of the suction pipe resting on the soil. By this the material to be dredged is sucked into the dredging pipe and is forced up into the delivery pipe without ever passing through the machinery. This system has been used abroad with good results.

Mr. Langley, the (then) chief engineer of the Great Eastern Railway, described in a Paper that was read before the Institution of Mechanical Engineers in 1882, the employment of one of the Ball dredgers (with a 12-inch suction) which was used at Lowestoft. The amount of material dredged averaged 200 tons of sand and shingle per hour, and this was raised from 7 to 25 feet high. At Angers, on the River Maine, near its confluence with the Loire in France, a dredger, with a suction pipe 11 inches in diameter, was used by Mr. A. Pellerin to remove sand which was effected at the rate of 106 tons per hour. The same contractor used a 9-inch dredger at Poole, in Dorsetshire, and moved 500 tons of fine sand per day from a depth of 9 to 12 feet, the material having to be deposited at a distance of 5 miles.

As the delivery pipe can be carried distances (by buoying or floating it, as already stated), it follows that this system of pump-dredging enables large amounts of material to be dislodged and deposited elsewhere without being brought on board, or even seen, in a very economical manner compared with the older methods of dredging.

The amount delivered by a Ball pump varies with the nature of the material dredged. The more it approximates to

sea-sand and beach the better the results, the nearer it resembles clay marl, or concreted gravels, the less are the quantities that can be moved.

Plants of 15 inches, 18 inches, and even 24 inches have been constructed, and, as a rule, the bigger the pump the better the results; the only difficulty then arising being the feeding of the dredger, a 24-inch pipe and plant, requiring a supply of at least 1,000 tons of solid material per hour.

HYDRAULIC POWER APPLIED TO BRIDGES.

The first application of hydraulic power to bridges was in 1852, when the Forest of Dean Railway Company constructed a hydraulic swing-bridge over the river Severn. A double leaf swing bridge of timber was constructed and worked by hydraulic power about the same time at the Birkenhead Docks. Each leaf of this bridge had a central hydraulic press of sufficient power to lift the leaf, and acting at the same time on the pivot upon which the bridge revolved. The tail end of the bridge was fitted with two rollers, which were brought in contact against an upper rail, so that, as the tail end was lighter than the nose end, when the bridge was lifted from its bearings, the rollers at the tail end were brought against the rail, and the pressure, being continued on the centre press, lifted the bridge clear of the masonry. The swinging of the bridge was effected by means of a hand rack and pinion, but as the bridge was carried on a water pivot it was easily worked. The bridge rested on masonry supports when not at work. The first operation of lifting the bridge off its bearings was performed in a few seconds, by turning the water from the accumulator into the centre press.

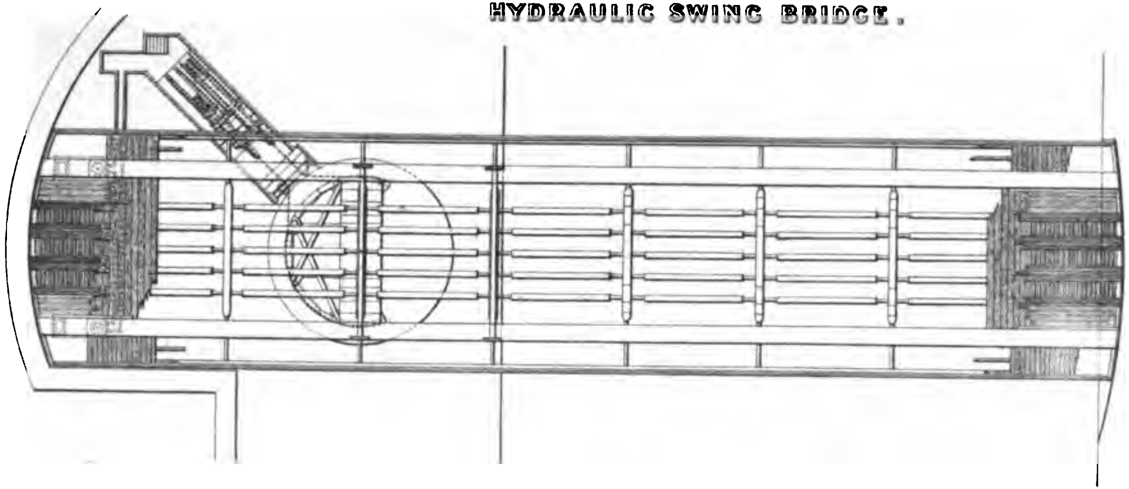
In some examples of the application of hydraulic power to swing-bridges a single press forms the water-bed. In others the ram is not attached to the bridge, but the end of it is made of a cup-shape, in which revolves the pivot that is

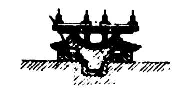
attached to the bridge. In some swing-bridges the tail end is made light. In others the tail end of the bridge is made heavy, so that when the bridge is lifted, the nose end is raised, the tail end resting upon a rail below the roller path. Occasionally it has been found advisable (as a stand by) to have a means of working the bridge by hand-power. This is done by using the centre press as a solid pivot, the ram resting upon the bottom of the cylinder, and the bridge revolving in a cup formed in the upper part of the ram. By means of presses applied to the tail end of the bridge, and worked by hand-pumps, it can be lifted or lowered to clear the bridge from its resting-blocks, and to leave it free to revolve.

Plate 50 shows a "hydraulic swing-bridge" constructed by Sir William Armstrong, Mitchell & Co. This bridge crosses a clear opening of 100 feet, and is adapted for both road and railway traffic. The clear width of roadway between the kerbs is 23 feet. The footways are on the outside of the main girders, and have each a clear width of 4 feet 10 inches. The bridge is designed for a rolling load of $1\frac{1}{4}$ tons per foot run on each line of railway, and for a concentrated load of 60 tons on four wheels. The main girders are of the triangular or braced construction, the cross-girders for carrying the roadway being fixed to the main girders at the foot of each system of triangulation, with longitudinal girders between the cross-girders under each line of rails. The bridge is lifted from its bearings (preparatory to being turned round) by a hydraulic press acting on a wrought-iron bearing-girder fixed to the under-side of the main girders. The turning motion is effected by two hydraulic cylinders acting, by means of chains, on a turning drum fixed to the under side of the bridge. A hand-pump is provided for use, in case the pressure from the main is not available. Should the centre press become disabled, provision is made for tilting the bridge from its bearings, by lowering the rear end wedge-resting block, hand-presses being provided for this purpose.

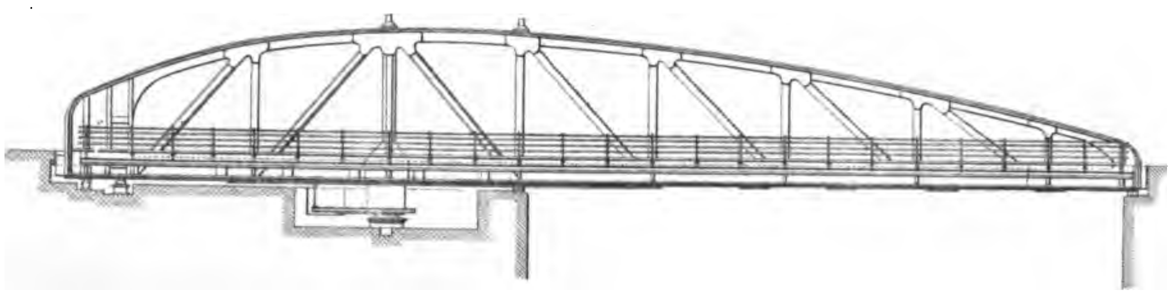
PLATE. 50.

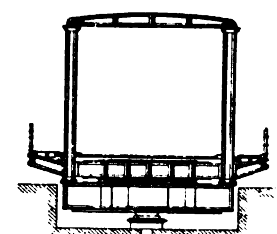
HYDRAULIC SWING BRIDGE.





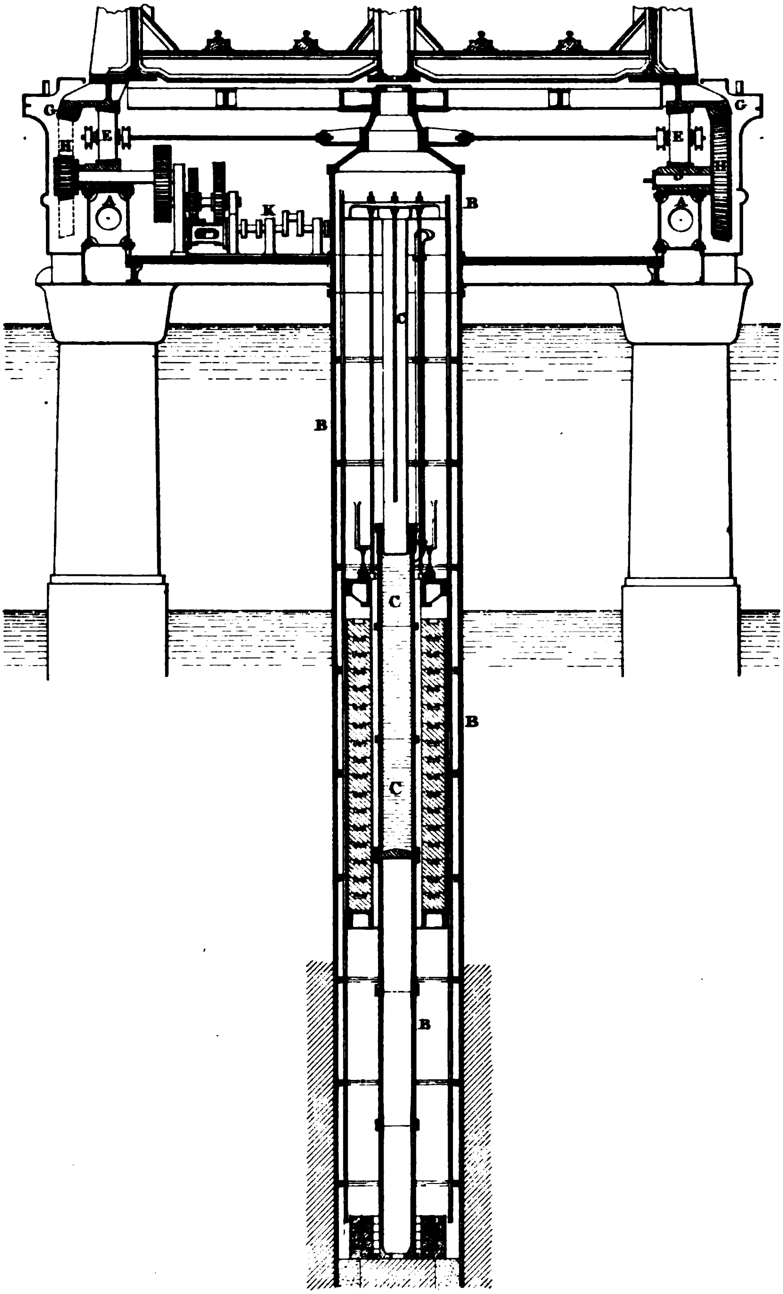
SECTION THROUGH CENTRE PRESS.





Scale.

Thos Kell & Son Lith



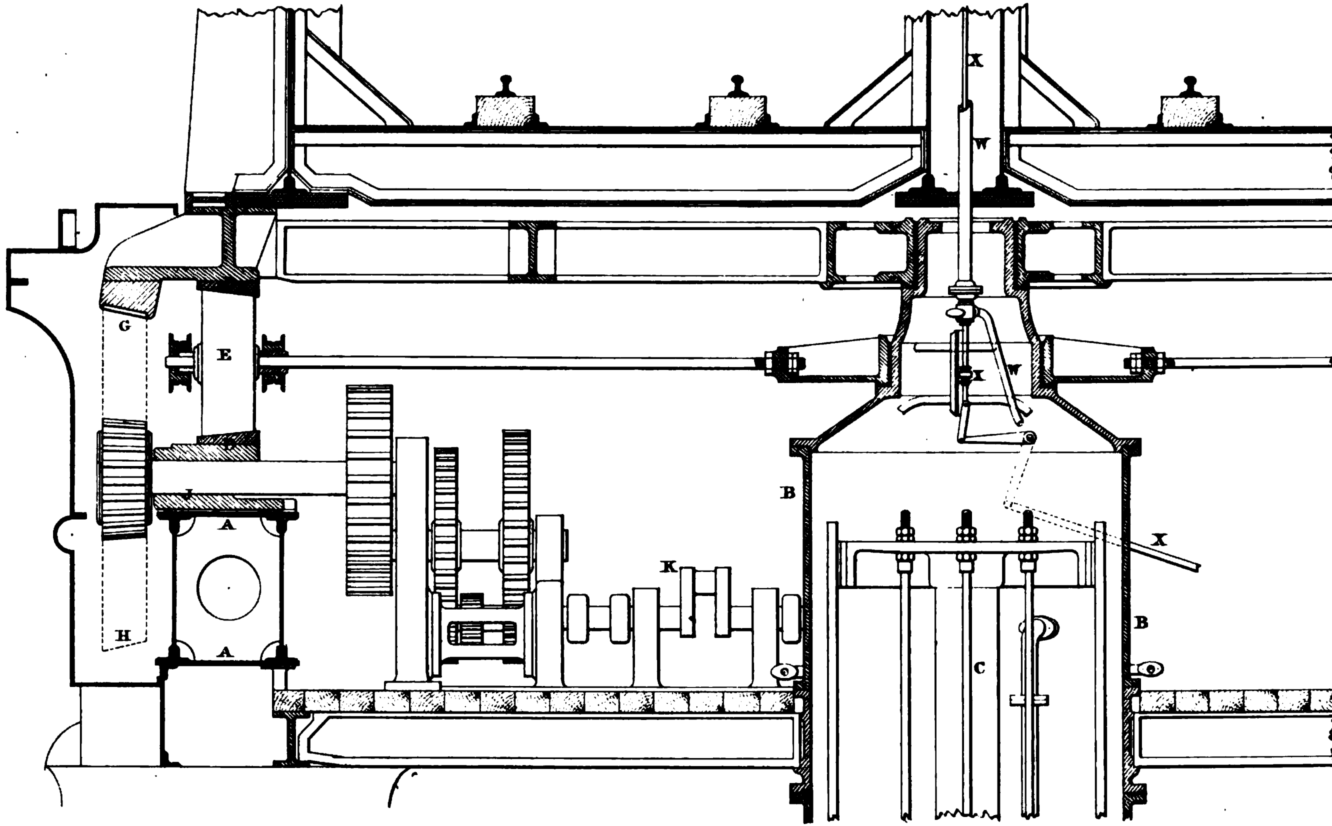
SECTION OF CENTRE PIER AND ENGINE ROOM.

Scale 1/4 inch

Feet 10 5 0 10 20 Feet

Thos Kell & Son, Lith.

OUSE SWING BRIDGE.



ENLARGED SECTION OF ENGINE ROOM.

Scale 1/48th

Ins. 12 6 0 1 2 3 4 5 6 7 8 9 10 Feet

Another form of swing-bridge, to which hydraulic power is applied, is that which rests upon a circle of live rollers, on a permanent roller path. The bridge is made to revolve either by means of one or more rotary hydraulic engines, placed on the centre pier within the circle of rollers, or by means of reciprocating acting rams and chains attached to the drum in the centre. The ends of each main girder are blocked by hydraulic presses after the bridge is closed.

The railway bridge over the river Ouse at Goole, which is one of the most important examples of this kind, was described by Lord Armstrong, when President of the Institution of Mechanical Engineers in 1869, and is shown by Plates 51 and 52. This bridge carries a double line of railway across the river Ouse, by means of three wrought-iron plate-girders, which, for the swinging portion of the bridge, are 250 feet long and 16 feet 6 inches deep in the centre. Plate 51 is a vertical transverse section at the centre pier, showing the engine-room and accumulator situated within it. Plate 52 is an enlarged section of one half of the engine-room. The centre girder of the three is strengthened, and rests on an annular box girder AA, 32 feet in diameter, which forms the cap of the centre pier. This cap rests on the top of six cast-iron columns, 7 feet in diameter, which are arranged in a circle and form the centre pier. A centre column BB, also 7 feet in diameter, contains the accumulator, and is attached to the others by cast-iron stays which support a floor. On this the steam-engine, boilers, &c., for producing the hydraulic power are fixed.

The weight of the swing-bridge is 670 tons, and it rests entirely on a circle of 26 conical live rollers, EE. These are 3 feet in diameter, with 14 inches width of tread, and run between the two circular roller-paths, DD, which are 32 feet in diameter and 15 inches wide.

The turning motion is communicated to the bridge by a bevel wheel H, which gears into a cast-iron circular rack, G, bolted to the outer circumference of the upper roller path. A steel pin, J, supported in the lower roller path, carries the

bevel wheel. This is driven by a pinion connected by intermediate gearing with a three-cylinder hydraulic engine (in duplicate) placed at KK, which exerts a force of about 10 tons at the radius of the roller path. The engines work at 40 revolutions per minute, with a water-pressure of 700 lbs. per square inch. The power is obtained from a pair of 12 HP steam-engines fixed (as before stated) in the engine-room formed beneath the centre of the bridge. Water is delivered into the accumulator C, which has a ram 16½ inches in diameter and 17-feet stroke, and is loaded with a weight of 67 tons.

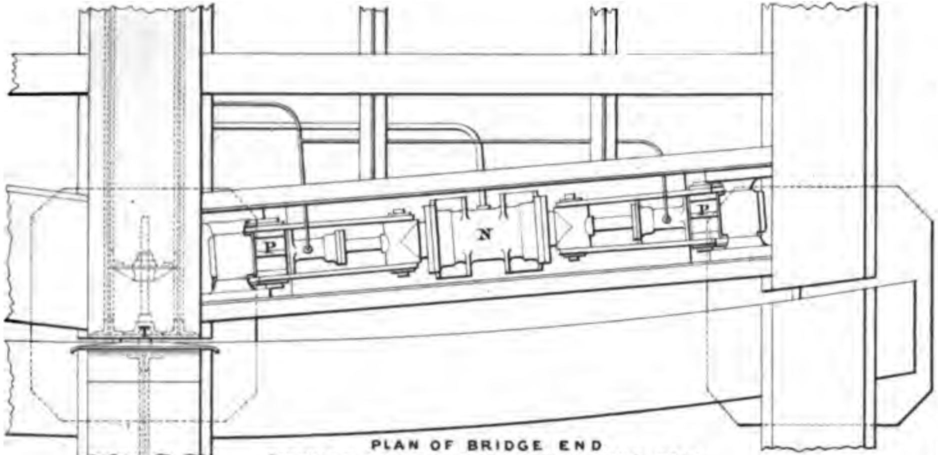
To secure a solid roadway, and a perfect continuity of the line of rails, an arrangement of gearing, shown by Plate 53, Figs. 1, 2, 3, and 4, is used. By this, each extremity of the bridge is slightly lifted by a horizontal hydraulic press N, acting on the levers PP, forming a "toggle joint." The press has two rams acting in opposite directions upon two toggle joint-levers, connected by a bar Q, which moves in a vertical guide to insure a perfectly parallel action of the two points. By this means the end of the bridge is made truly parallel when the resting-blocks RR, under each girder, are put into position. To do this, three separate hydraulic cylinders, SS, are employed, as shown by Figs. 3 and 4. When the toggle joint-levers, PP, are withdrawn, the bridge is lowered on the blocks. The hydraulic cylinders N and S are controlled by valves on the centre platform in reach of the bridgeman, who can stop the bridge at the right place by means of a dial with pointers actuated by the motion of the bridge. When the motion is stopped, a locking-bolt T, 3 inches thick (which is pressed outwards by a spiral spring) is shot out at each end of the bridge into a corresponding slot, and so locks the bridge. These bolts are withdrawn by the wire cord U when the bridge is to be swung.

The line of the bridge being north and south, a slight lateral warping is caused by the sun acting alternately on the opposite sides of the bridge. To enable the bolts to enter their slots

OUSE SWING BRIDGE,

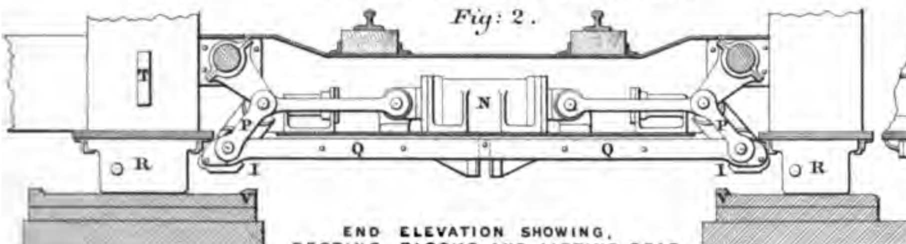
LOCKING GEAR &c AT ENDS OF BRIDGE.

Fig: 1.



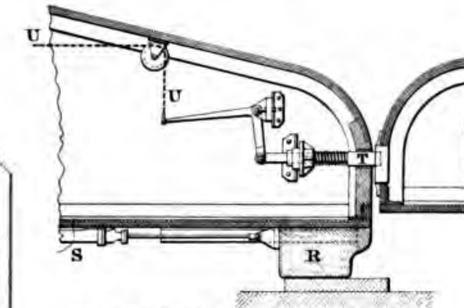
PLAN OF BRIDGE END
SHOWING LOCKING BOLT AND LIFTING GEAR

Fig: 2.



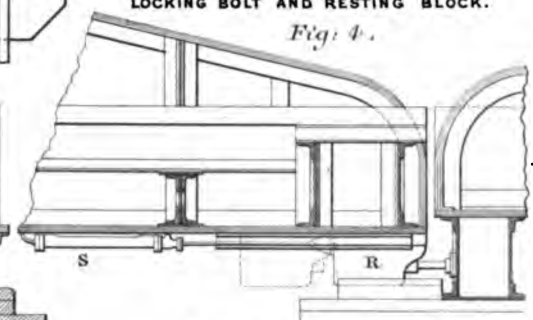
END ELEVATION SHOWING,
RESTING BLOCKS AND LIFTING GEAR.

Fig: 3.



LONGITUDINAL SECTION, SHOWING
LOCKING BOLT AND RESTING BLOCK.

Fig: 4.



SIDE ELEVATION
SHOWING RESTING BLOCK.

Thos Kell, & Son. Lith.

when the warping occurs, the feet of the lifting levers PP are bevelled on their inner faces at II (Fig. 2), and bear against corresponding bevels VV on the bed plates, by which means the ends of the bridge, when warped, are forced back into the correct line.

The accumulator being stationary, whilst the fixing gear swings with the bridge, the water-power is conveyed by a central copper pipe W (Plate 52), which passes up through the centre of the bridge, and has a swivel joint at the lower end. As the hydraulic turning-engines are also stationary, whilst the bridgeman's hand-gear rotates, the communication for working the valves is made by a central copper rod X (Plate 52), which passes down through the centre of the pressure pipe W in the axis of the bridge. The opening or closing of the bridge is accomplished in 50 seconds, the average speed of motion of the end of the bridge being 4 feet per second.

Small gas jets are provided in the central pier, and in the chambers containing the hydraulic cylinders, and are kept burning in very frosty weather. The pipes leading to the machinery at the ends of the bridge are protected by cinders encased in wooden boxes.

Another important hydraulic swing-bridge is that which crosses the river Tyne. The swinging portion of this is 280 feet long, and weighs more than 1,200 tons. In this bridge, instead of the weight resting upon live rollers, a hydraulic press is applied to the centre; it has a pressure of about 900 tons upon the ram, which relieves the pressure upon the rollers to that extent. The rollers and roller path, however, are sufficiently strong to carry the whole weight of the bridge, supposing any accident were to happen to the centre press. The central press being always open to the accumulator pressure, a permanent relief is afforded without any waste of power.

Hydraulic power was first applied to drawbridges in 1853 to work the bridge over the river Tovey, on the South Wales

Railway near Carmarthen; and at the Sunderland docks a hydraulic drawbridge was constructed about the same time. In the application of hydraulic power to drawbridges, the first operation consists in lifting the bridge sufficiently high to enable it to roll back over the permanent way in the rear. The lifting presses then act directly under the main girders of the bridge, and, as the tail-end is heavier than the nose-end, the nose-end of the bridge is first raised against the roller bearings, and then, when the back-end is raised to its proper level, the bridge is hauled back by means of hydraulic reciprocating engines. These act upon rollers, either attached to the bridge itself (in which case the rollers run upon a roller path fixed to the masonry) or upon rollers attached to the head of the lifting ram, when the roller path is attached to the bridge itself. A noticeable bridge of this type has recently been constructed at the Kattendyk entrance to the Antwerp Docks.

Hydraulic power has also been applied on the "Bascule" (or old lifting drawbridge) system, both single and double leaf. A bridge of this character occurs over one of the dock entrances at Liverpool. Sometimes the dip of the "Bascule" bridge is counterbalanced by the tail-end of the bridge. In some cases the bridge is hinged on the quay level, and is lifted bodily back, leaving the passage of the quay-way perfectly free and uninterrupted for passengers. There is a Bascule bridge at York in one leaf of 34 feet, which is raised by chains actuated by hydraulic rams. At Copenhagen, again, there are seven Bascule bridges, one of which, having two leaves of 62 feet each, is in the very centre of the city, and has to carry a large portion of the traffic across the harbour. It is worked by hydraulic machinery, and has been opened and closed fifty-five times in a day. A Bascule bridge to cross the Thames near the Tower is now in course of construction, the first stone having been laid by the Prince of Wales in June 1886, Mr. J. Wolfe Barry being the engineer. The Bascule portion of the bridge, which constitutes the centre opening, is in two leaves 50 feet in width (made up with a roadway of 36 feet, and

Fig: 1.

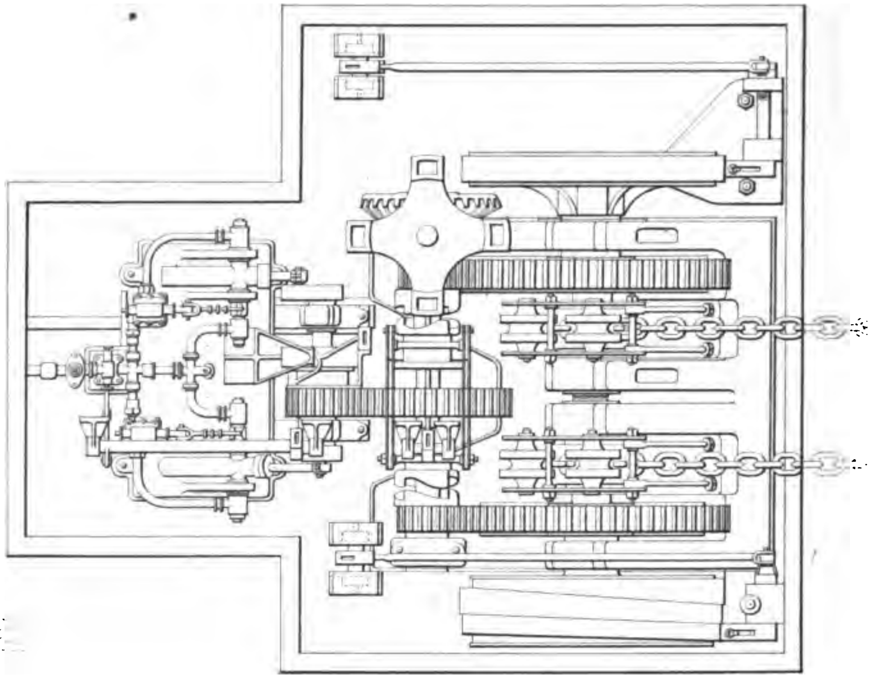
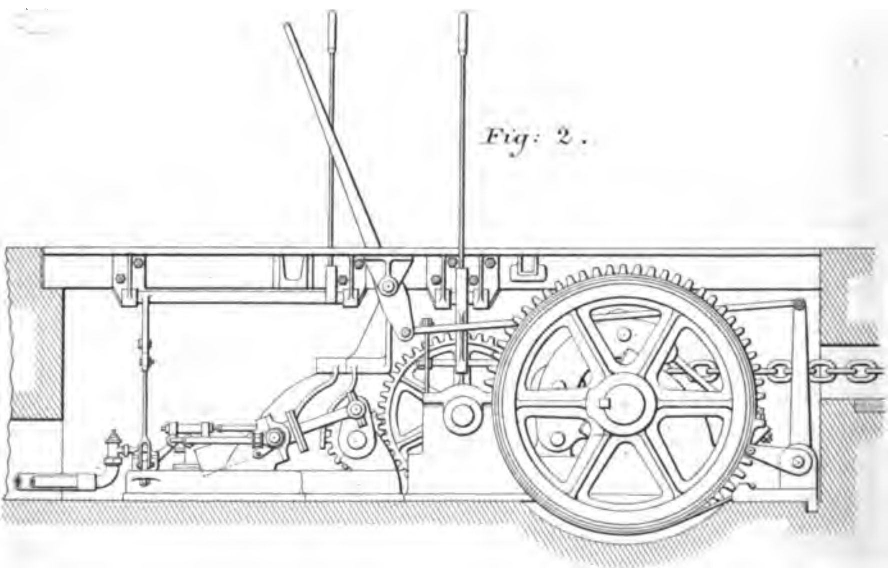


Fig: 2.



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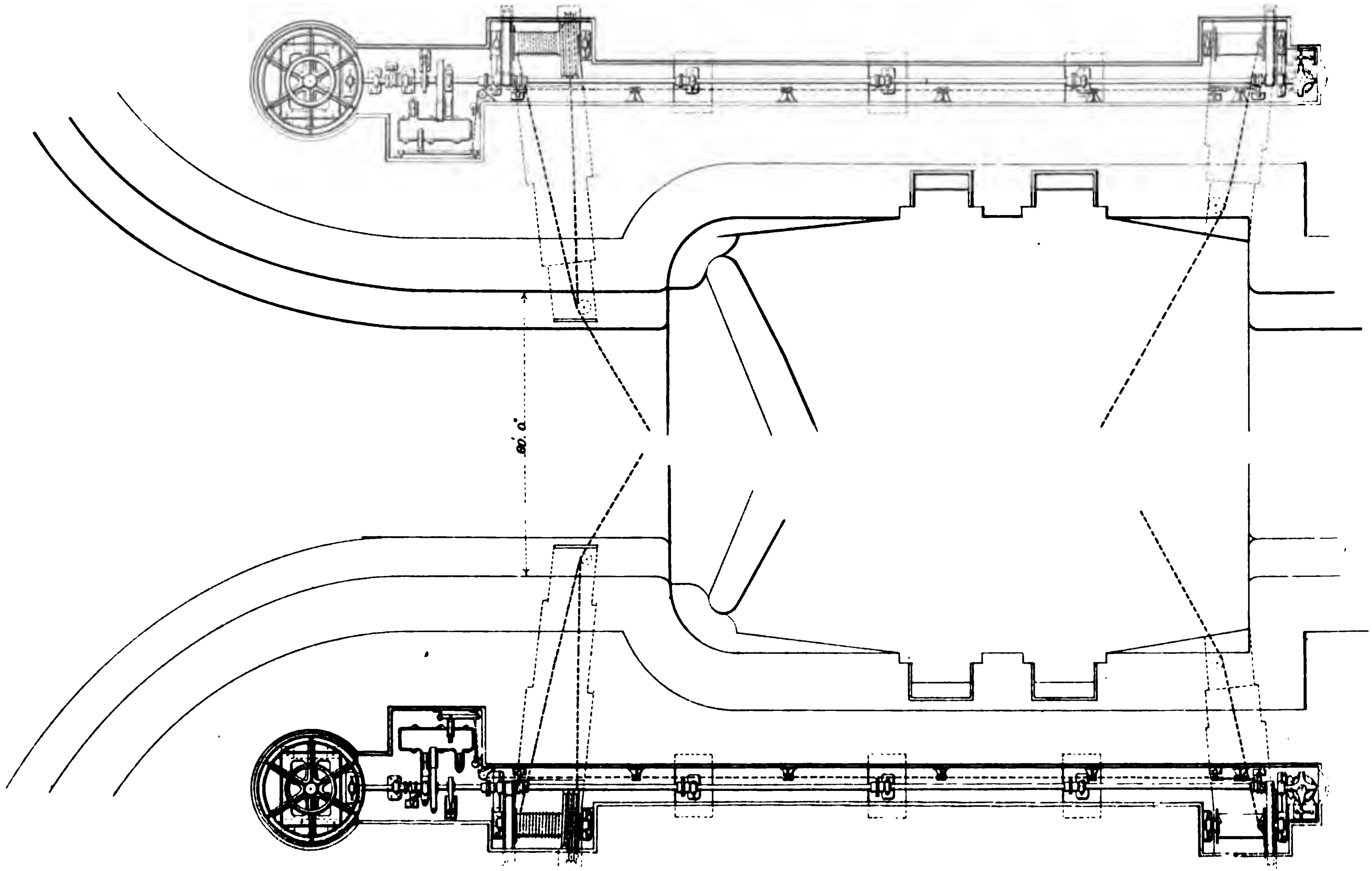
HYDRAULIC CAPSTAN

AND GATE OPENING AND CLOSING MACHINERY FOR 60 FEET LOCK.



Thos Kell & Son Lith

two footpaths of 7 feet each), and 200 feet span, each leaf being therefore 100 feet. The leaves of this bridge are to be raised and lowered by hydraulic machinery.

DOCK-GATE MACHINERY.

One of the first applications of hydraulic power in this direction was to the old hand-power gate machines at the docks at Newport and Swansea. Lines of shafting were carried along the dock wall, with gearing connecting the engines to each of the hand crabs. This shafting was actuated by rotating hydraulic chains, which at the same time worked capstans at the extreme end of the dock.

Hydraulic engines were next applied directly to each crab, instead of through intermediate shafting. An "Elswick gate crab," with hydraulic engine attached, is shown by Plate 54, Figs. 1 and 2. In this arrangement there are two rotary hydraulic engines with two cupped drums to each, a clutch enabling either drum to be thrown into gear with the engine, whilst the other overhauls. One engine with its double crab serves for two chains, which are led along the top of the gate. The chain for opening passes over a pulley, and descends vertically by the side of the gate. After passing over another pulley, it is attached to the masonry at the place where in ordinary practice the roller-box is fixed. By this arrangement the old method of making chainways in the masonry is obviated, and each leaf of the gate is worked both ways from the same side.

Another arrangement is that by which hydraulic power is applied to the crabs through shafting driven by hydraulic engines. Plate 55 shows a "Hydraulic Capstan and Gate Opening and Closing Machinery for 60-feet Lock." By this method the opening and closing chains are led from the gates through roller-boxes in the masonry of the walls, and thence up inclined chainways to separate winding-drums. These are

worked by shafting from three-cylinder hydraulic rotatory engines (one on each side of the lock). The closing drums have a spiral at the end for taking up quickly the slack chain lying across the lock. When the opening drums are hauling in, the closing drums are paying out, and *vice versâ*, to effect which the drums are connected to the shafting by clutches. The drums are controlled by brakes when paying out. The shafting can be worked by hand, by means of a sunk capstan-head, in case of need. A capstan for hauling ships is also connected to shafting by a clutch and bevel spur gearing.

Another form of gate machinery is the direct-acting ram and cylinder with multiplying sheaves, which has been very generally adopted, although it does not provide for the working of the gates by hand in case of need, or if the power is not available. Plate 56 shows a "Hydraulic Machine for Opening and Closing 80-feet Lock Gates." The opening and closing chains are led from the gates through roller-boxes in the face of the walls, and up inclined chainways, to horizontal hydraulic cylinders and rams. These have multiplying sheaves, around which the chain is led, the end of the chain being attached to the cylinders. On pressure being admitted to the opening cylinder (by means of a valve in a pit adjoining), the ram is forced out, drawing up the chain, opening the gate, and pulling in the closing ram on the other side of the lock, which (by means of its valve) has been put in connection with the exhaust. For closing the gates, the operation is reversed. The ram-heads are carried by rollers on tram-plates. This arrangement is simple, and has very few wearing parts. The strain on the chain when the gate is moved is about 10 tons. The gates are opened in a minute and a half.

The illustration only shows the machinery on one side of the lock. The other is precisely similar.

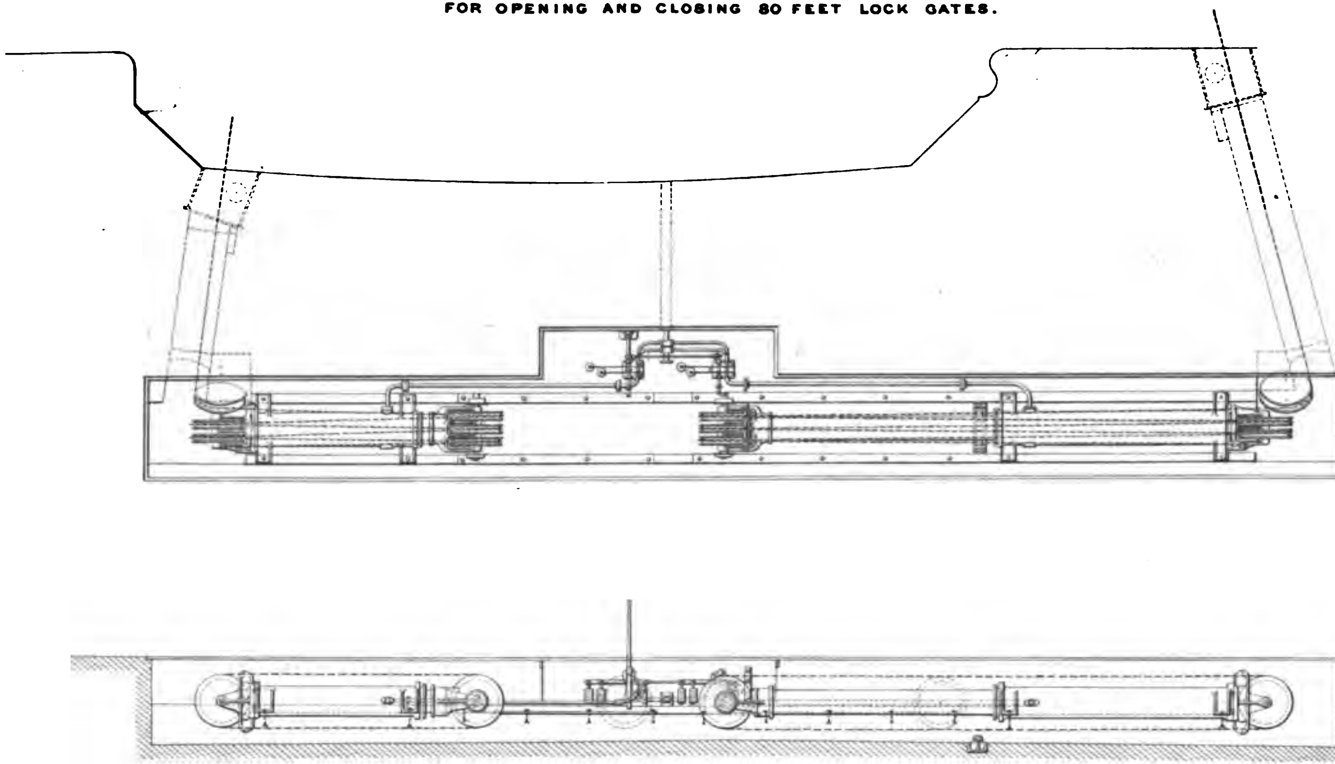
The widest entrances to which hydraulic power has been applied are 100 feet at the Canada Dock, Liverpool, at the Barrow Dock, and at Birkenhead.

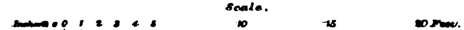
Sluices for removing mud at the entrances to locks can be

PLATE. 56.

HYDRAULIC MACHINE,

FOR OPENING AND CLOSING 80 FEET LOCK GATES.





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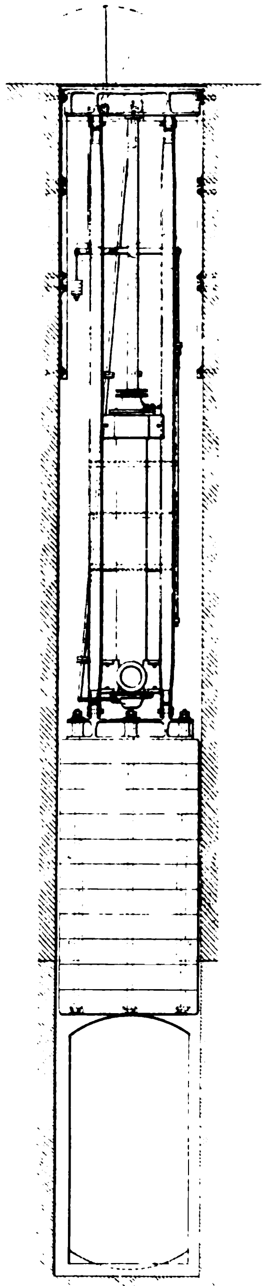
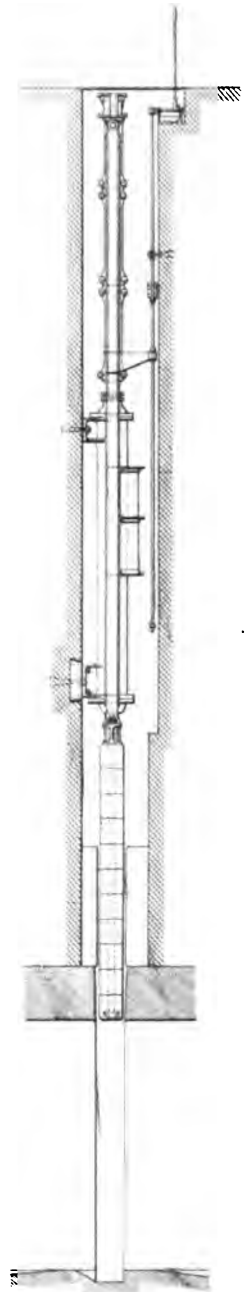
DIRECT-ACTING HYDRAULIC SLUICE MACHINE.





Scale.

Inches 12 0 1 2 3 4 5 10 15 Feet

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conveniently worked by hydraulic machinery. Their movement up and down is effected by the application of direct-acting cylinders and pistons attached to the masonry to open and close the paddle against the pressure. A hand-pump is generally applied so as to be available in the event of the water-pressure being accidentally cut off. The combination is effected by a screw and gearing worked by a rotary hydraulic engine, so arranged that it can be worked by either hand or power. The sluice cylinders are usually lined, and the rods covered, with copper. Plate 57 shows an Elswick "Direct-Acting Hydraulic Sluice Machine." At the Alexandra Docks, Newport, the hydraulic sluices are attached to the gates themselves, instead of being placed on the masonry.

Lock-sluicing arrangements at dock entrances have generally failed by reason of the scouring action of the water on the mud being limited to the mouth of the sluice. Deep holes are made there, as the scouring force is not operative at any distance from the sluice. A solid apron should therefore be carried for some distance beyond the mouth of the sluice to prevent the force of the water from disturbing the floor (as it frequently does). The current would then be directed with the best effect, and the formation of the upper eddies, which destroy the sluicing power of the water, would be avoided.

HYDRAULIC BRAKE.

A brake or buffer can be made by enclosing a volume of water in a cylinder that is provided either with a perforated piston or with a small pipe connecting each end of the cylinder, which admits the passage of water slowly from one end to the other. Such an appliance admits of wide application in arrangements of machinery where the absorption of suddenly arrested energy is required. In working the starting and reversing gear of marine-engines, the piston-rod of the steam

cylinder is continued and forms the piston-rod of a hydraulic brake cylinder, the ends of which are connected by a small pipe through which the fluid is pressed backwards and forwards. When the piston begins to move, the resistance of the brake is at a minimum, increasing with the motion of the piston (as the square of the speed) till a maximum is reached, which is adjusted by means of a cock.

Mr. Alfred A. Langley devised an "hydraulic buffer stop" for the purpose of preventing accidents due to trains over-running terminal stations, or dead ends, on railways, and arising either from the failure of the brakes, defects in the machinery, or carelessness in not reducing speed. A description of this was given to the Institution of Mechanical Engineers in 1886.

The principle on which it is based is the application of hydraulic resistance by the use of a piston working in a horizontal cylinder filled with water, and fixed in line with the buffers of the rolling stock. Plate 58 illustrates this appliance. Figs. 1 and 2 show a sectional elevation and plan of the general working arrangements. The piston-rod A working in the cylinder B is of solid steel, $3\frac{3}{4}$ inches in diameter, and 13 feet 1 inch long over all. Upon its extremity is fixed a buffer head, similar to those of the rolling stock. In its normal position (ready to receive a train) it projects 6 feet from the face of the cylinder, allowing 2 feet for the construction of a fixed stop, as shown at L. This consists of four permanent-way rails placed transversely across the front end of the cylinders, two over and two under the piston-rod, and connected together by a loose girder through which the rod passes. The cylinder B is shown in sectional plan by Fig. 5. It is 4 feet $7\frac{1}{2}$ inches long, cast with a flange on each end, and bored out to 12 inches diameter, with $2\frac{1}{2}$ inches thickness of metal. Covers are bolted to both flanges, and are fitted with hydraulic glands, with cup leather packing, for the piston-rod, which passes through both ends of the cylinder. An india-rubber ring 1 inch thick is fixed round

HYDRAULIC BRAKE.

Fig: 1.

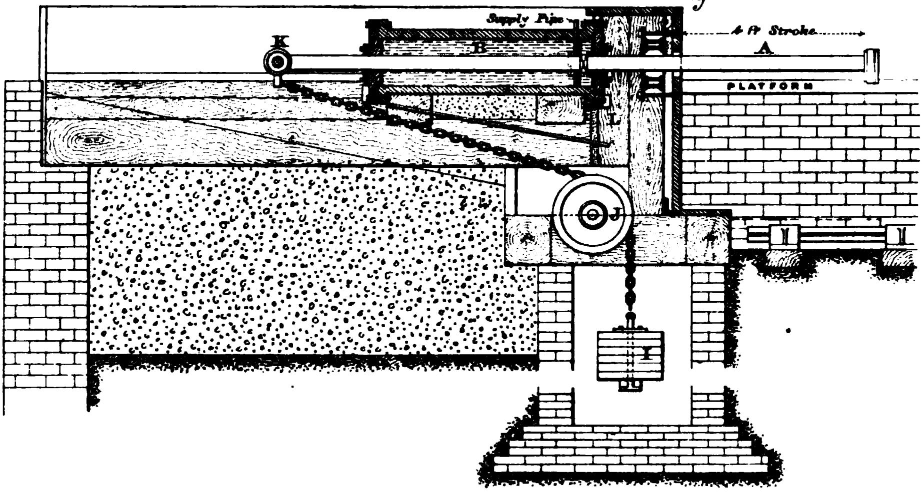


Fig: 2.

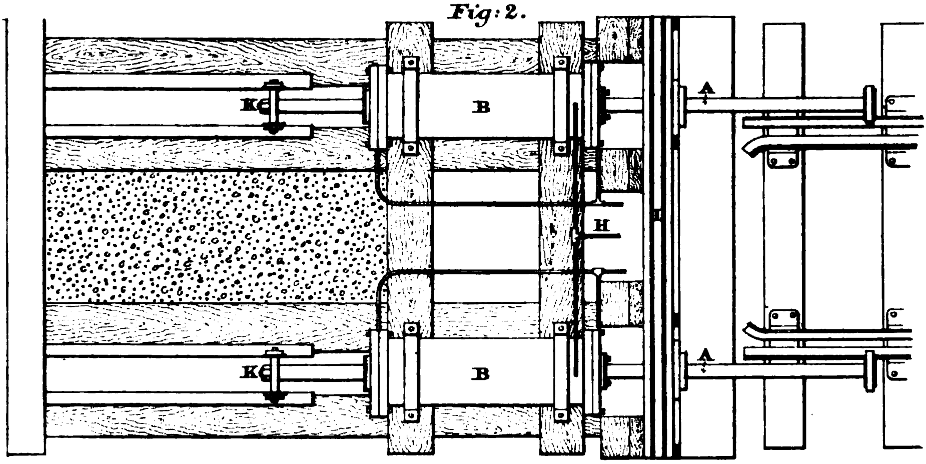


Fig: 3.

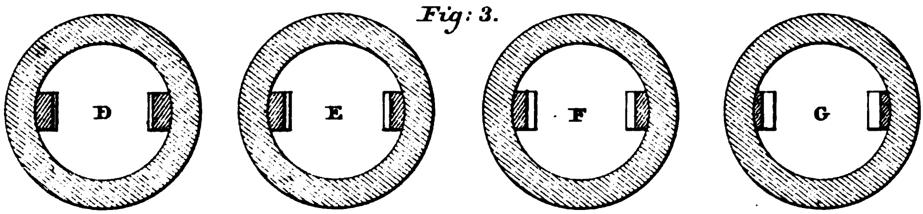


Fig: 4.

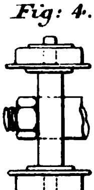
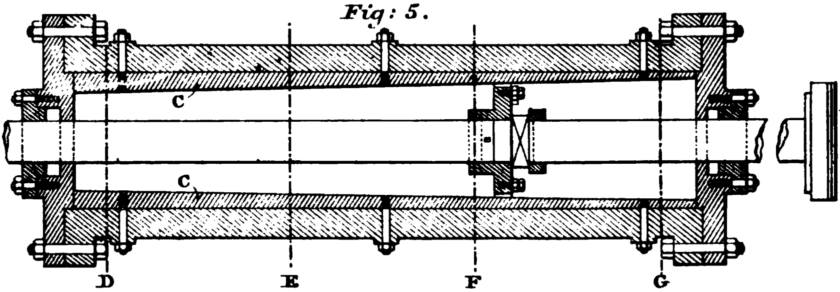


Fig: 5.



Thos Kell & Son, Lith.

the rod on each side of the piston, to form a cushion between the piston and the cylinder ends, the piston being turned to an easy fit. The constant circumferential clearance between the cylinder and the piston is 0·38 of a square inch. In addition to this constant space, a gradually diminishing area of passage has been contrived, whereby a uniform resistance is maintained throughout the stroke. This is accomplished by a wrought-iron strip C, 3 inches wide, fastened by stud-screws along each inner side of the cylinder. They project $\frac{9}{16}$ of an inch into the cylinder at the commencement of the stroke, and taper up to $1\frac{1}{16}$ inch at the rear end. This wrought-iron strip fits into a corresponding slot $1\frac{1}{16}$ inch deep, which is cut out in each side of the piston.

When an impact takes place, the piston is forced backwards. The clear space between the tapering strips and the slots in the piston becomes less and less, as shown by the diminishing areas of the waterway (the thin rectangular strip with the hatching) in sections GFE and D, so that, notwithstanding the diminishing speed, an equal amount of resistance is maintained until the train is at rest. The waterway of G is 4·96 square inches, of F is 3·18 square inches, of E is 1·40 square inch, and of D is 0·08 of a square inch. By means of adjusting screws, applied to gauge plates, the proper sizes of the openings through the pistons were determined by experiment. The cylinder is kept constantly filled with water by a supply pipe H fixed to the front of it. When released, the piston is drawn forward again into its original position by the action of a counterweight I, suspended in a pit under the forepart of the buffer by a $\frac{3}{4}$-inch chain, which passes over a fixed pulley J under the cylinder, and is attached to a crosshead K upon the back end of the piston-rod. This crosshead has a wheel on each side (as shown in detail in Fig. 4) running along a guide path. The counterweight is composed of cast-iron discs, with a packing of felt between each, and a packing of india-rubber between the bottom weight and the holding bolt, to take the first strain

upon the chain, when the buffer is struck. Each buffer is designed to work separately, in order to avoid the unequal compression which might occur if two were connected by a cross-head.

It has been found by experiment that a train having a speed of at least eight miles an hour is brought to a stand with less than a 4-feet stroke. The theory of the action of the stop is considered to be, that its resistance varies as the square of the velocity of the train, while the momentum of the train also varies as the square of its velocity, so that the piston-rods will be forced back, on impact taking place, through the same actual stroke (approximately), whatever be the velocity.

HYDRAULIC POWER APPLIED TO GUNNERY.

Lord Armstrong and Mr. Vavasseur, in a paper that was read at a meeting of the Institution of Naval Architects held in Newcastle in 1887, gave particulars of the application of hydraulic power to naval gunnery. They pointed out that the increasing weight of guns necessitated the employment of some power greatly superior to mere hand labour, whilst the increasing speed of ships rendered it essential to provide for acceleration in the rate of firing. The simplicity and compactness of hydraulic machinery, and its suitability to the transmission of power through long distances, enabled it to be utilised to absorb the increasing energy of recoil in modern guns. The desiderata are, sufficiency of resistance to absorb the energy, and automatic action. The first apparatus was the "Elswick Compressor," in the design of which, as well as in the application of hydraulic power to gunnery, Mr. George Rendel's name will be always identified. The Compressor consisted of a number of short iron plates on the gun-carriage, interlacing long plates or bars on the slide, in such a manner that both could be clamped together by the vice action of a

piece called the compressor jaws, and a very great frictional resistance produced when the carriage was set in motion. As the number of these plates was limited by the breadth of the slide, the "Compressor" in time became inadequate for the increasing recoil of the more powerful breech-loading guns of modern form. An hydraulic buffer was next employed which was fitted to the slide. A packed piston worked in the buffer, having the piston-rod attached to the gun-carriage. The recoil of the carriage caused the piston to force the water through loaded spring valves into a waste-water tank, the valves being adjusted to give the resistance due to the maximum charge. The variation in the charge produced a variation in the length of the recoil, which was objectionable, whilst the sudden opening of the valves, resulted in their being forced back too far, and their recoil produced an abnormally high pressure. The Vavasseur Compressor Brake was devised to remedy these defects. It consists of a pair of hydraulic cylinders forming part of the upper gun-carriage, and in them work pistons attached to the slide. The piston heads are made solid on the piston-rods and are a loose fit in the cylinders, having no packing. In the head is a recess with a disc or valve (free to turn on the piston) fitted on the periphery of which are tongues projecting into grooves rifled in the cylinder. Ports are made in the valves of a form to give uniform pressure during recoil, openings to correspond to them being cut in the piston head. At the commencement of recoil the ports in the disc are in line with those in the piston-head and therefore are full open. As recoil proceeds and the tongue on the disc revolves in the rifle groove, the disc gradually closes the ports. When they are nearly shut the liquid is unable to pass freely from one side of the piston to the other, and the recoil is stopped.

The cleaning and loading of guns is also performed by hydraulic power, several systems having been devised for that purpose. One consists of an hydraulic tube rammer, in which the head formed a sponge for cleaning the bore. It also

contains a self-acting valve which opens when it is pushed against the end of the bore, and which discharges a strong jet of water within the gun. The rammer head is so arranged that this valve does not come in contact with the shot when ramming it home, nor does the valve open in ramming home the cartridge, the resistance being sufficient to bear the pressure against the bag without yielding. By these appliances two men control all the movements of a pair of the heaviest guns, and load and fire them without other help than that required to bring up the ammunition. In applying hydraulic power to these purposes, the water is pumped direct into the pipes without passing through an accumulator.

For land defences, hydraulic and hydro-pneumatic gun-carriages have been constructed for raising and lowering guns, so that the loading can be done at a low level (under the protection of a fortification), and the gun can then be raised above the parapet to be fired.

Major Moncrieff has utilised the power which is developed in the recoil of a gun, by storing it for raising the gun. In the Moncrieff hydro-pneumatic gun-carriage, the recoil of the gun, mounted on the "disappearing" principle, is taken by a combination of water and air. When air alone is employed, a practical difficulty exists in expelling the whole of it from the recoil cylinder. The small volume of air that remains is under greater pressure than is necessary for balancing the weight of the gun, and this produces a partial recoil. The arrangement which obviates this, consists of a water cylinder and air-vessel, connected by a passage fitted with an automatic valve, which opens from the cylinder towards the air-vessel. The force of the recoil is transmitted through the ram in the water cylinder to the elastic medium of the air in the air-vessel. This, however, cannot react upon the water owing to the intervention of the valve. The elasticity of the air becomes an agent for storing the energy of recoil for utilisation in working guns on this principle. This is accomplished by opening a communication between the water in the air-vessel

and the hydraulic cylinder, by which the air-pressure forces the gun upwards into position for training. By these arrangements a gun is raised into position by the power which has been derived and stored during firing. After the gun has been fired it retires of itself, and the force of the recoil is absorbed and stored. The construction of the Moncrieff hydro-pneumatic gun-carriage has been chiefly carried out by Messrs. Easton & Anderson. Sir William Armstrong, Mitchell & Co. have also applied a hydro-pneumatic disappearing carriage to Armstrong guns.

CENTRIFUGAL PUMPS.

For raising large quantities of water a small height, a "centrifugal pump" (which is practically an inverted turbine) is a very suitable form of pump. Appold constructed the first, and it has been the basis of all subsequent ones. In this form of motor it is necessary to bear in mind that the greatest efficiency can be only obtained when it is applied to work under a constant head. The calculations on which the shape and design of the motor are based, show that an equally good result cannot be obtained when the head is variable. A velocity of about 5 feet per second for the flow of the suction and discharge water is generally regarded as that which should be aimed at. The disc friction varies as the square of the diameter, and the loss due to total frictions increases as the cube of the velocity. Experiments with centrifugal pumps have established an efficiency of about 50 per cent. in the small pumps, and about 70 per cent. in the large pumps. The shape of the curved vanes of the fan materially affects the results, the best form being that in which these are bent backwards. Professor Unwin has shown by his experiments on the "Friction of Disc Rotated in Fluid" (recorded in the *Proceedings of the Institution of Civil Engineers*) the conditions which require to be observed in

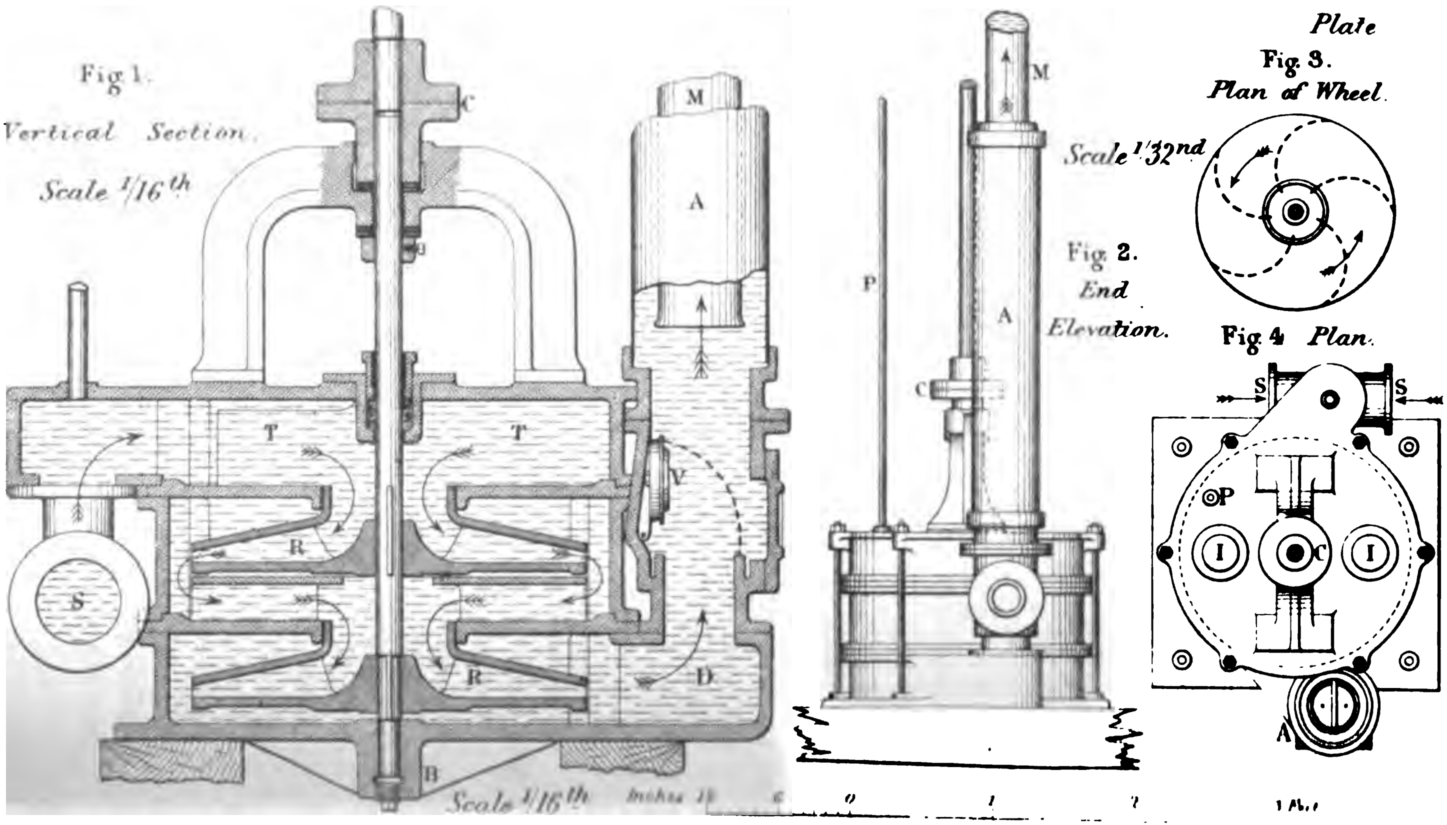
order to minimise the loss of efficiency in turbines and centrifugal pumps. This loss is largely due to the friction of their disc-shaped surfaces in the water surrounding them. The larger the chamber in which the disc rotates, the greater is the friction of the disc, which is attributable to the stilling of the eddies by the surface of the stationary chamber. The stilled water reacting upon the surface of the disc causes the friction of the disc to be dependent, not only on its own surface, but also on the surface of the chamber in which it rotates.

A "Chinese" (or "Scoop") wheel is simply an overshot water-wheel with reversed motion, by which water is caught up in the buckets of the wheel as it revolves, and is raised to a height nearly equivalent to the diameter of the wheel. For low lifts of about 10 feet, and for large volumes of water, this form of pump has an efficiency of upwards of 80 per cent. The diameter is usually from four to five times the height of the lift, and the speed of the periphery should be about 8 feet per second. This kind of motor is adapted to the draining of fen lands. In California the Chinese pump is extensively employed for low lifts for irrigation purposes. It consists of an endless band (generally a pair of ropes) passing over pullies at the top and bottom of a slope; the bands carry a series of wooden floats or cross-bars fixed to the outer face and travelling in an open trough, by which water is raised from a stream at a low level and is delivered into carriers for distribution at a higher level. For slopes of about 20° and for lifts of about 6 feet this is a very economical method of raising water.

Mr. Wilfrid Airy has designed an "Archimedean Screw" pump for lifting fluids, which illustrates the great efficiency obtainable from a motor which is designed to avoid loss of energy from eddies or shocks in the translation of the fluid. A description of this pump was given to the Institution of Civil Engineers in 1871. It consists of a rotating cylinder, having a central core, and one or more spiral passages. It

IRRIGATING MACHINERY.

COMPOUND CENTRIFUGAL PUMP.



works in a frame at an angle of 30° to 45° with the horizon, and the velocity of rotation is about 3 feet per second, measured on the periphery of the cylinder. The lower end is placed in the water to be raised, and the upper end is attached to the delivery. In the working of a well-constructed Archimedean screw pump on this plan, an efficiency as high as 85 per cent. is obtained. The feature in this motor is that the spiral threads are made on the "developable" system, or that by which a curved surface can be unwrapped, laid flat, and made into a plane.

As the speed at which a centrifugal pump should be run increases approximately as the square of the height of lift, the revolving wheel has to overrun the flow in that increasing degree, whilst the effect due to impact falls off with the increasing velocity of the wheel. In low lifts the over-running diminishes in the same degree, whilst the effect due to impact is increased. To meet the difficulties that arise where centrifugal pumps have to be used for high lifts, and in a space too limited to allow of a single wheel being constructed large enough to give the required velocity, compound pumps have been employed, by which both the size of the wheels and casing, as well as the speed, have been lessened. An arrangement of pump on this principle has been successfully carried out by Mr. John Richards of San Francisco, and, as the compounding of centrifugal pumps has not been much employed, mention will be made of one that was described by him to the Mechanical Engineers in 1888.

Plate 59 shows a compound pump with two revolving wheels, R. The driving shaft is coupled to the pump spindle at C, the bottom bearing being at B. A charging pipe P is carried down from the surface above, and the pump is charged either by a steam ejector or an air pump, always at the top of the pit. The charging is not done by water, as foot valves are not employed. The foot of the delivery main M is surrounded by an air-vessel A. The water is drawn by suction into the top chamber T, whence it passes downwards through

the two wheels R, and out to the discharge chamber D, through the delivery valve V, and up the rising main M. There are five curved vanes to each of the shrouded wheels, as shown in plan by Fig. 3. Besides the double inlets SS, there are two more inlet orifices in the top cover, at I I, shown in plan by Fig. 4, for attaching two more suction pipes, but the four inlets are not often required. The air-vessel A is desirable for deep pumps.

WATER WHEELS.

In considering the application of water to wheels, the variation of level of the water determines the character of the wheel to be employed. The rise in the stream, and in the level of the water for a given width of wheel, is sometimes greater than can be utilised in the open bucket of an overshot wheel. A variation of level of 2 feet, and a velocity of the periphery of the wheel of 5 feet per second, are the usual limits. When the water is received by the wheel below the summit (generally between the axis and the lowest point), it is called a "Breast Wheel." In this case the supply is regulated by an adjustable sluice, over which the water flows to vanes on the wheel, which are substituted for buckets. A channel of brickwork or stone surrounds the wheel, and in this the vanes move. The water, filling this channel, acts by its weight in turning the wheel. The efficiency of an overshot or breast wheel sometimes reaches 75 per cent., but a lower efficiency of about 65 per cent. is a safer estimate, unless the wheel is very well designed and constructed.

In the ordinary overshot wheel, the open buckets of wood or iron are shaped so as to prevent the water shooting over the wheel. This is also obviated by making the capacity of the bucket sufficient to hold about three times the volume of water discharging into it. The buckets are placed between two shrouds, and the power acting on the wheel is measured

by the volume of water, and the height through which it falls. If F is the net fall in feet, Q the weight of water per second in pounds, then the gross horse-power acting on a wheel will be—

$$\frac{Q\ F \times 60}{33,000}$$

In the "undershot" waterwheel the water acts by its momentum at the bottom of the wheel. When small falls of 6 feet or so, or rapid currents, have to be utilised, the undershot waterwheel, as perfected by General Poncelet, is a most efficient prime mover. Beyond that fall the wheel has to be large and costly to give much power, and a turbine is preferable. Even when the undershot waterwheel is working under favourable conditions, at least one-half of the energy due to the fall is lost. The water impinging on the floats imparts some of its energy to the wheel, but it loses part through eddies and breaking up. After it has acted on the floats, again, it passes away from under the wheel with a velocity at least equal to that of the wheel, all of which velocity represents lost energy. About 25 per cent. of loss may be attributed to each of these causes, although in good undershot wheels 60 per cent. of efficiency is possible.

Poncelet adopted the following rules as enabling the best results to be obtained:—The water should impinge on the curved buckets at the bottom of the wheel at an inclination of 1 in 10. The diameter of the wheel should be twice the depth of the fall. The velocity of the periphery of the wheel should be arranged to be 55 per cent. of the velocity due to the head, measured to the centre of inlet. The fall and volume of water being known, the power of a wheel is determined thus, taking 60 per cent. of efficiency:—

Q = Volume of water in cubic feet per minute.
HP = Effective horse-power.
F = Fall in feet.
530·5 = Cubic feet of water per minute falling 1 foot = 530·5 × 62·2 = 33,000 ft.-lbs. per minute = 1 horse-power.
c = efficiency.

Then

$$HP = \frac{Q \times F \times c}{530 \cdot 5}$$

If

$$Q = 3000 \text{ cubic feet per minute.}$$
$$F = 4 \text{ feet.}$$
$$c = 60 \text{ per cent.} = \frac{60}{100} = \cdot 6.$$
$$HP = \frac{3000 \times 4 \times \cdot 6}{530 \cdot 5} = 13\tfrac{1}{2}.$$

In America the "Pelton" waterwheel is reported to have an efficiency as high as 80 per cent., owing to the substitution of cups for flat floats. The water is delivered to the wheels through nozzles of from 1 inch to 2 inches diameter, and the water impinges on the wheel like a jet striking a hollow cup. The water is thus not broken up, but spreads and exhausts the whole of its energy in the cup.

TURBINES.

In the old "Barker's Mill" or "Reaction Wheel," water passes downwards through a vertical tube, which forms the axis of a horizontal tube, having holes at its extremities through which the water issues. This produces a rotative action, but it also causes the water to have a rotary velocity after leaving the tubes of the reaction machine, which involves a loss of power. This attracted the attention of Fourneyron, and led to his inventing the "turbine." By means of guide blades fixed in an external case, he gave the water a forward motion before it entered the wheel or internal case which revolved on the axis of the machine. This resulted in the water passing out of the machine at right angles to the axis, without a backward velocity, thus avoiding the corresponding loss of energy.

Turbines are classified into radial, axial, and combined or mixed flow. In radial turbines the water passes through the wheel in a direction at right angles to the axis of rotation. In axial turbines the water passes through the wheels in a direction parallel to the axis of rotation. In the other cases both the radial and axial are combined. Some turbines work with all the parts under water and these are called "Reaction" turbines; other turbines are constructed with the buckets only partly filled with water, the rest of the space having air in it, these are termed "Impulse" turbines. In both cases there are guide vanes to direct the entry of the water to the buckets of the wheel. The machine devised by Fourneyron forms essentially the basis of the numerous turbines which have been subsequently invented by Jonval, Professor Thomson, Schiele, Girard, and others. In well-constructed turbines, the loss of energy due to velocity after the water leaves the machine varies from 5 to 8 per cent. The loss from skin friction depends on the size and form of machine.

A series of experiments by Mr. Lehmann on thirty-six turbines, varying from 1 to 500 HP, led to the following estimate of losses:—

Loss per cent. due to	Axial Flow.	Outward Flow.	Inward Flow.
Hydraulic resistances, . . .	12	14	10
Unutilised energy, ...	3	7	6
Shaft friction, ...	3	2	2
Total, ...	18	23	18
Efficiency, ...	0·82	0·77	0·82

In ordinary practice, the efficiency of a turbine should not be taken at more than from 75 to 80 per cent., although it is claimed that a higher efficiency has been obtained in some turbines.

The power of a turbine can be calculated by the method given for waterwheels "*c*" varying from ·75 to ·80.

Lord Armstrong in speaking at the Institution of Civil

Engineers in 1888 pointed out that there was a wide field for the employment of water at high pressures in directions other than by direct pressure derived from accumulators. He referred to the ingenious steam turbine, invented by The Hon. C. Parsons, which made 10,000 revolutions a minute, and considered that what could be done by steam could be done by water, although the existing types of turbine would require modification. He thought it was practicable to construct a turbine to work at any pressure usually supplied from accumulators. If a reduction in pressure, however, were needed, that could be effected, and a current of high-pressure water could be converted into a larger volume of water at a lower pressure.

JET PROPULSION.

The application of the hydraulic jet to the propulsion of vessels has been the subject of experiments of a more or less practical form, and of patents dating as far back as 1661. During recent years the system has been tested by the construction of several vessels which were propelled by hydraulic jets, with the result of producing much controversy amongst experts in naval matters. A paper by Mr. Barnaby (read before the Institution of Civil Engineers in 1884) gives a description of the most recent experiment, in the construction for the Admiralty of a torpedo boat by Messrs. Thorneycroft. This was fitted with a turbine propeller, and the design of this boat provided for utilising as much as possible the velocity of the feed-water. Just in front of the pumps the bottom of the vessel had a sudden jump upwards from the stern and towards the bow end. At this point the bottom is formed into a great scoop, which gently rises to the inlet of the pump, which is placed at an angle to reduce the effect produced by the change of direction of the feed-water entering.

The velocity of this entering water causes it to rise in the scoop, and the vanes of the pump are adjusted to pick up the water without shock, and gradually to accelerate it to the speed of discharge. The peripheral velocity of the pump is 56 feet per second. The energy acquired by the water is utilised by discharging it through nozzles to orifices in the vessel above sea-level. These nozzles are 9 inches in diameter, formed of copper pipes bent to a radius of 18 inches, and so pivoted that either end can be presented to the discharge orifice in the side of the vessel. The amount of water passed through the pumps in fifteen seconds is equal to the whole displacement of the boat. The water is discharged at a velocity of 37·25 feet per second (about 1 ton per second being discharged with a lift of $21\frac{1}{2}$ feet), the speed of the boat being 21·4 feet per second (or 12·65 knots per hour). Careful experiments were made by means of a thin plate $1\frac{5}{16}$ inch square, attached to the end of a lever and placed in the jet, just where it left the nozzle. The pressure on this plate was recorded by a dynamometer attached to the other end of the lever, and the lever was arranged so as to enable the plate to be shifted about, and the pressure to be recorded over the whole jet. The mean pressure was found to be nine-tenths of that in the centre. Professor Rankine's formula for the efficiency of the jet is as follows:—

$$\text{Efficiency of jet} = \frac{\frac{w\,v\,s}{g}}{\frac{w\,v\,s}{g} + \frac{w\,s^2}{2g} + \frac{f\,w\,v^2}{2g}}$$

$f = \cdot 0374$;
w = weight of water discharged in lbs. per second;
v = speed of vessel in feet per second;
s = slip or acceleration imparted by the propelling apparatus;
g = 32·2 feet per second.

When the energy of the feed water is lost the waste per second may be expressed by $f\,\frac{wv^2}{2g}$; f being a multiplier

whose value may range from an insensibly small fraction to unity, according to the suddenness with which the velocity of the feed is checked.

The efficiency of the jet was found to be ·71, and of the pump ·46. The efficiency of the jet and pump combined was ·33, this being the useful work of the jet divided by the effective HP. The total efficiency was ·25, this being the useful work in the jet divided by the indicated HP.

A comparison of the efficiency of a jet propeller with a screw propeller was made by Mr. Barnaby as follows:—

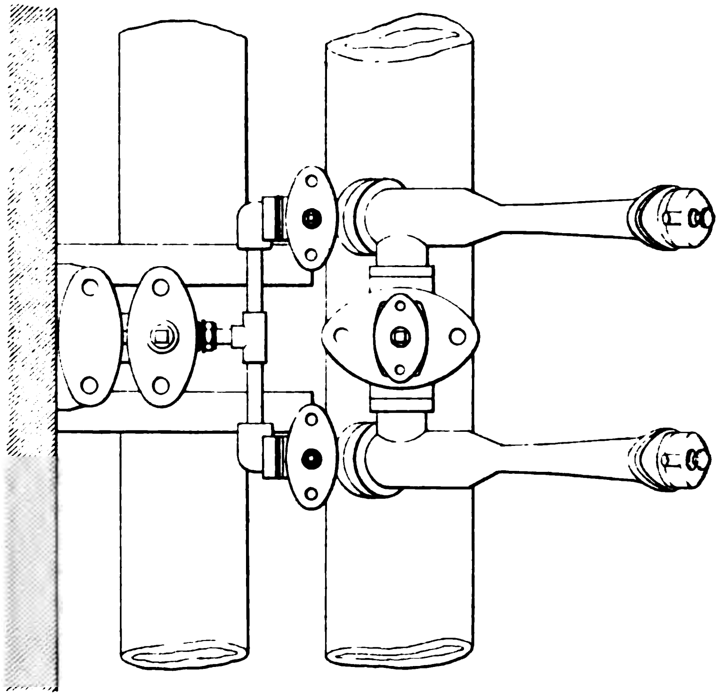
Screw Boat Efficiencies. Engine, ·77; screw propeller, ·65; total, ·5.

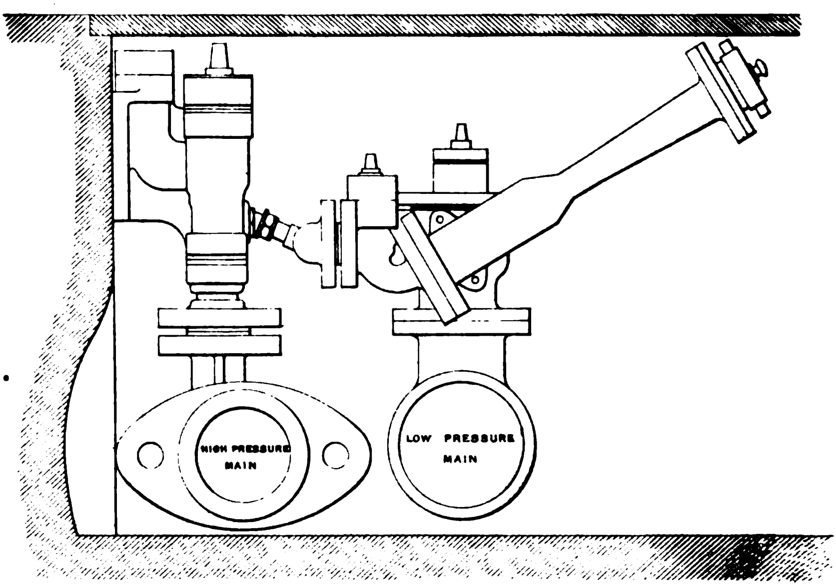
Hydraulic Boat Efficiencies. Engine, ·77; jet propeller, ·71; pump, ·46; total, ·254.

THE GIRARD-BARRÉ HYDRAULIC RAILWAY.

M. Barré has carried to a practical success an idea that occupied the attention of M. Girard many years ago, when he was perfecting the turbine with which his name will be always associated. The project was to construct a vehicle with a smooth bottom that would be in contact with a flat surface upon which it could slide. By directing a current of water under pressure between the two surfaces, the tendency will be both to keep them apart and to cause motion in the direction of the current, by which the vehicle would be propelled. A successful illustration of this principle was afforded at the Paris Exhibition in 1889, where a tramway was shown in operation. The vehicles were supported on slides, resting and moving on plate rails having a broad even surface. A pipe fitted to the slide enabled a current of water at 150 lbs. per square inch to be directed between the two surfaces, thus preventing metallic contact by a thin film of water. The under sides of the carriages

INJECTOR HYDRANT.





Scale, 1 Inch = 1 Foot.

Inches 12 11 10 9 8 7 6 5 4 3 2 1 0 1 2 Feet

Thos Kell & Son Lith

had bucket racks attached to them, like troughs fitted with cross blades, against which was directed the current of water from the main, and so caused the propulsion of the carriages. The stream of water was controlled by valves, by which the speed could be varied, or by shutting off the supply the water film disappeared, and the metallic contact between the surfaces of the slides and rails provided a brake.

M. Barré stated that the water required to propel the train was 8 gallons per ton per mile. The line which was 500 feet in length having a fall at each end, was traversed by the carriages in half a minute. The mechanical details were worked out with great ingenuity, and the system was quite deserving the interest that was taken in it. A water-borne train like this was proved to be a perfectly practicable undertaking, and where water under pressure is available at small cost, the greater outlay on works that is involved in constructing such a system may be justified commercially.

GREATHEAD'S INJECTOR HYDRANT.

Mr. Greathead has perfected an appliance by which a jet of water from a high-pressure main is passed into a stream of water from a low-pressure main, which causes the stream of low-pressure water to be carried to a greatly increased height. If the lines of motion of the two currents were identically the same, so that no loss was sustained from eddies, the force communicated to the mass of water at the low velocity would represent exactly that which the high-pressure water had lost.

Plate 60 shows one of the Greathead "Injector Hydrants" as applied at the Royal Albert Docks, London.

Many experiments have been made to ascertain the quantity of high-pressure water that would be required to produce jets of water at various low pressures. The following table is deduced from experiments with a low-pressure supply from 10 to 20 lbs. per square inch, and with a high-pressure of

700 lbs. per square inch. The quantity given in the table is for a jet of 150 gallons (delivered through a 1-inch nozzle) variously estimated to ascend to a height of from 75 feet to 84 feet, and requiring a pressure of 100 feet head at the back of the nozzle. The length of hose is taken at 200 feet of 2½-inch brigade hose, the resistance of which, for that discharge, is taken at 3 inches of head per foot of hose.

Quantity of High-Pressure or Power Water required for Various Heads of Low-Pressure Supply to produce the Jet described.

Low-Pressure Supply.		High-Pressure at 700 lb. per square inch.
Lbs. per square inch.	Feet head.	Gallons per minute.
60	138	3·7
50	115	10·9
40	92	18·1
30	69	25·2
20	46	32·4
10	23	39·6

Mr. Greathead has for some years advocated the application of these hydrants, by the public bodies, for the extinction of fire. It is well known that the pressure in the mains is not, except in isolated cases, sufficient for giving powerful jets of water without the intervention of fire engines. Mr. Greathead proposed that injector hydrants should be placed under the footways, and be connected with the constantly charged mains of the water companies, and with a high-pressure supply-pipe deriving its water from accumulators and pumps driven by gas or other engines placed at the fire brigade or police stations. Upon a hydrant being used, the nearest accumulator would fill and start the engine and pumps automatically in the ordinary way, and thus, in the case of a large fire, involving the use of a number of jets, several stationary engines would come into operation. The power would thus be available on the occurrence of a fire exactly where and when it was required.

Up to the present time the hydrants have only been adopted

in London by private persons for the protection of themselves and their property, though in Hull the Corporation have put them down in parts of the City.

At the time when this proposition was first made, there were no hydraulic mains in the streets of London. At the present time there are many miles of such mains, and mostly in the important streets and places. Injector hydrants attached to these mains would give a security against fire not hitherto possessed by any portion of the metropolis.

Another application of the injector hydrant is for drainage purposes. The iron tunnels, for instance, of the City & South London Railway are kept free from the condensed vapour which collects in the inverts of the tunnels in considerable quantities in certain conditions of the atmosphere. There the hydrants derive their supply of high-pressure water from the hydraulic mains from which the lifts at the stations are worked, and which run through the tunnels. Their merits for this and similar purposes are that they occupy very little space and cannot get out of order, having no working parts. Those on the City & South London Railway go into a space of not more than 12 inches long and about 3 inches in diameter, and with a high-pressure nozzle of about $\frac{1}{16}$-inch give a discharge of about 100 gallons per minute through a 2-inch pipe to and up the nearest shaft into the street drains.

SNELL'S HYDRAULIC TRANSPORT SYSTEM.

A system has been designed by Mr. H. de Morgan Snell for the transmission of goods over long distances by hydraulic power. It is claimed that, where large quantities of goods in bulk have to be carried over considerable distances, the cost of conveyance by this system is so small that if the rates of freight charged were reduced to one half of those at present charged by the railway companies, a large profit would be obtained upon the capital employed. The principle may be

stated thus:—If a vertical pipe be filled with water and a body of higher specific gravity than water, and of less diameter than the pipe, be introduced at the top, it will sink to the bottom, or if a body of less specific gravity than water be introduced by suitable valves at the bottom of the pipe it will rise to the top. If a current of water be maintained in a horizontal, vertical, or inclined tube, and a body having the same specific gravity as water and of less diameter than the tube be introduced, it will be carried along by the current at the same velocity, and if the specific gravity of the body differs within certain limits from that of the water it will still be carried along by the current though at a somewhat diminished velocity.

If the bodies introduced into the water in the above cases are hollow, watertight, and contain material, such material can be conveyed from place to place in precisely the same way as solid bodies, and a regular system of water carriage can be established.

If a line of water pipes be laid from A to B, and if a current be maintained in the pipe, then carriers containing goods can be inserted in the pipe at A and will in due time be delivered at B, and if a return pipe be laid from B to A and a return current be maintained in the water, the carriers, after having been emptied of their contents at B and refilled, can be conveyed back from B to A. Again, if a line of pipes is laid upon an upward incline from A to B, and carriers with their contents are, by means of suitable valves, introduced into the pipe at A, if the carriers and their contents are slightly less dense than the water they will rise in the tube and will be delivered at B, and if, after having been unloaded at B they are reloaded and made somewhat denser than water, they will sink down to A, and a regular system of traffic can thus be carried on between A and B by keeping the pipes full of water, and by providing suitable means for introducing and extracting the carriers. If it is not convenient to regulate the weights of the carriers and their contents so that each

carrier may have the requisite density to either rise or fall along the pipe, the floating or sinking power may be obtained by attaching separate light or heavy bodies to the carriers so as to produce the required effect. By laying rails inside the pipes and by furnishing the trucks with wheels the difficulties can be met that would arise from friction against the sides due to difference in specific gravity. If the trucks are so loaded as to be heavier than water, the wheels will bear upon rails fixed in the lower half of the pipe, while if the trucks are lighter than the water, the wheels will bear upon rails in the upper half.

It has been assumed by the inventor that for general application the pressure to which the pipes and trucks may be subjected may reach, but not exceed, 100 lbs. per square inch. This head will generally be divided into that due to irregularities in the contour of the ground along which the pipes are laid and that due to the pressure required to maintain the velocity of the current.

The pipes are proposed to be laid in two parallel lines, one line serving for up, the other for down, traffic. These pipes are to be connected at each end, so as to form a complete water circuit. The pumps for producing the current are preferably placed at the highest point of the circuit with these advantages,—first, that the head of water, against which the pumps have to work, is only that required to maintain a suitable velocity of water through the total length of the two lines of pipes, and is irrespective of any difference of level along the pipes; and, second, that the weight of water in the two pipes is balanced, and as the trucks and their contents are, in the aggregate, practically the same weight as the water which they displace, the up and down traffic is balanced.

The economy in working that is claimed for this system is based on the following:—First, the effect of gravity when going up and down gradients is practically eliminated, and the power required is the same, whether the section of the line of communication is level or undulating. Second, that

the motive power, instead of being obtained from a locomotive engine, is obtained from stationary pumping-engines. Third, the trains by the hydraulic system are driven automatically, and no attendants accompany them. Fourth, the weight of locomotive, &c., upon the rails, the high speed, and the brake action upon descending gradients, are eliminated. Fifth, passenger traffic is excluded by the nature of the system, with the savings incident thereto.

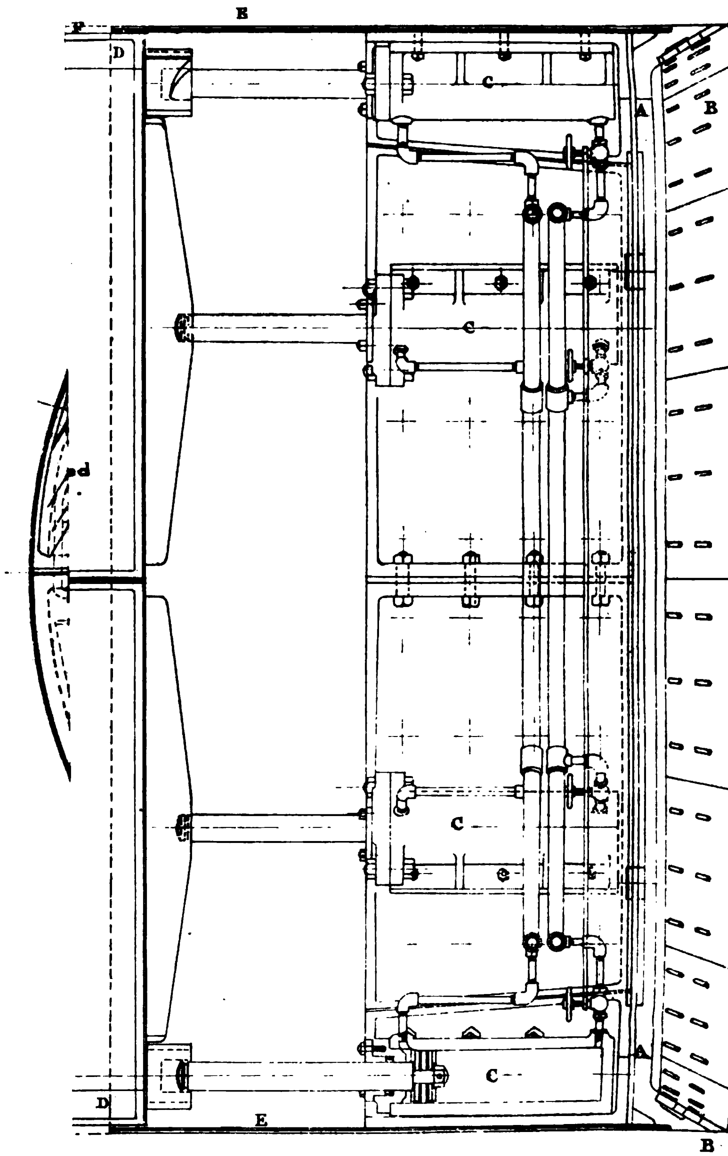
There are many points of interest and of commercial importance in this proposal, and a practical trial of the system deserves to be made.

GREATHEAD'S SHIELD.

In the construction of the tunnels under the Thames for the City & South London Railway (about 6½ miles in length) hydraulic power was used with great effect by Mr. Greathead. This railway extends from the City to Stockwell, and passes under the Thames near London Bridge. It consists of two separate tunnels placed relatively to one another in any desired position, sometimes one over the other and sometimes side by side. The tunnels are lined with cast iron in the form of rings and segments, and the excavation was done by means of shields, within which the segments were built up into a continuous cylinder. Powerful hydraulic rams, pressing against the forward end of the already completed cylinder, forced forward the shield, and caused it to excavate for itself a space exactly equal to its own diameter, and at each advance a length equal to that of one of the rings of the tunnel lining.

With the exception of about 200 yards at Stockwell, the whole line was executed under, and for a considerable length through, water-bearing strata. When the tunnels were actually through, or very near to, water, they were constructed under compressed air, to avoid pumping the water,

Fig: 2.



West, Newman Photo.

and special appliances and precautions had to be adopted to prevent the escape of the compressed air in such volume as to permit inflow of water.

On occasions as much as 16 feet were driven, and on an average 13 feet 6 inches of tunnel were completed, daily at a face. In one period of six months, 2¼ miles of tunnel were completed at the several faces then working.

The shield consisted of a steel cylinder overlapping the forward end of the iron tunnel. At its front end is a strong and rigid diaphragm A (see Plate 61, Figs. 1 and 2) having an

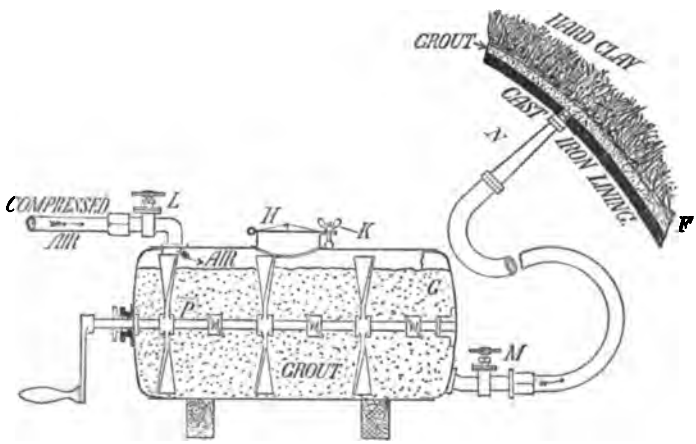


Fig. 51.

opening or door in it. Beyond this face project adjustable steel cutters B, and behind it are the hydraulic presses C ranged round the circumference, and so fixed as to abut against the forward end of the completed tunnel D. As the material is excavated by the cutters and loose wedges (not shown in the illustration) in front of the shield, and thrown back by the miners through the opening in the face, the shield is forced forward by the presses. When it has been forced forward sufficiently far, a fresh ring of iron lining is built up inside, and under cover of, the overlapping steel cylinder E. In its advance the shield clears out a circular space, somewhat larger than the outside diameter of the iron lining of the

tunnel, thus leaving an annular space, F. This space is filled with grout composed of blue lias lime, and in some cases of cement, by means of the apparatus shown in Fig. 51. The lime or cement is mixed with water in the cylindrical vessel G; when of the proper consistency the lid H is closed and held down, air-tight, by the screw K. Compressed air brought down in a small pipe from a receiver and compressor at the shaft, and having a pressure of 30 lbs. to 50 lbs. per square inch, is then admitted through the valve L on to the surface of the grout in the vessel G. The lever valve M being then opened, the grout is discharged through a length of flexible hose and branch N into the annular space F. By means of the paddles and handle upon the spindle P, the contents of the vessel are first thoroughly mixed and then prevented from setting in the "grouting pan." Holes are provided in each segment for this operation of "grouting," which is of primary importance in tunnelling under streets, houses, water-mains, &c., and is also most useful in preventing the escape of air when the tunnel is driven under compressed air through water-bearing gravel, sand, &c. The shell of lime or cement also forms an excellent protection to the outside of the iron lining.

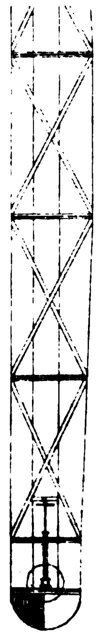
GRAIN ELEVATOR AT FRANKFORT.

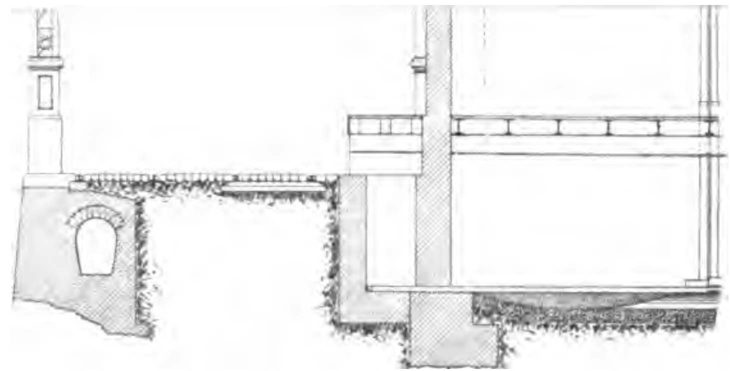
Mr. W. H. Lindley, the engineer to the Magistracy of Frankfort.-on-Main, has furnished an illustration of the Grain Elevators which are in operation in the New Harbour there.

Plates 62 and 63 show the general arrangement, the object being to raise grain from ships and barges alongside the quay by a telescopic tube containing within it a series of buckets working vertically, and lifting the grain from the hold and delivering it to the surfaces of endless bands, which convey it to the various floors of the granaries for storage.

GRAIN ELEVATORS, FRANKFORT.

PLATE 62.





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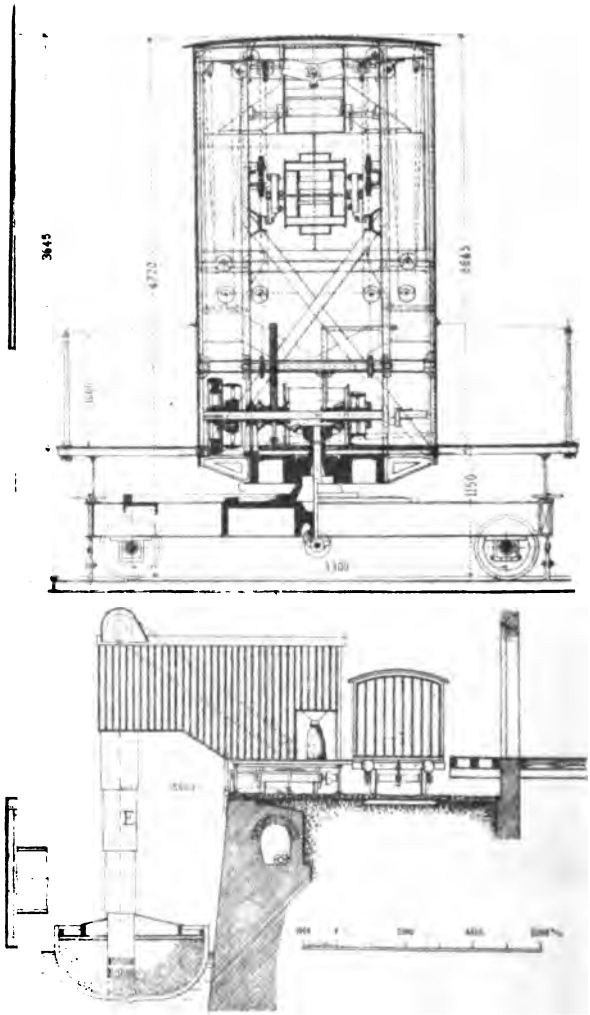


West, Newman Photo.

In order to raise the grain from the barges, a stationary elevator is fixed on to a swinging arm, at a distance of 7½ metres from its axis, as shown by Plate 62. The weight of the elevator and of the swinging arm A is partly counterbalanced by a number of weights. When the swinging arm is in a horizontal position the whole of the counterbalance weights are in action, and when the swinging arm is raised further up, the weights gradually come out of action. The counterbalance weights are connected to the elevator by means of two wire cables BB, and in such a way that the depression of the swinging arm takes place owing to the weight of the unbalanced part of the elevator, and it is raised by means of the wire ropes CC running over the winding drums of the windlass D. An improvement has been introduced by substituting for the counterbalance weights hydraulic arrangements.

The grain lifted from the barges is taken from the top of the elevator by means of an india-rubber band and is conveyed either to automatic scales, or to the transporting belts, for distribution and storage in the granaries, provision being made for dealing with 36 metric tons per hour, or 6 sacks per minute each of 100 kilos or 220 lbs.

In order to supplement the stationary grain elevator at the Granary a portable grain elevator has been erected, as shown by Plate 63. This elevator has a radius of 5 metres, and transports the grain from the barges to the two automatic scales AA and the arrangements for filling and removing the sacks at B. This, as well as the Stationary elevator, is capable of dealing with 36 metric tons of grain per hour, or 360 sacks each of 100 kilos or 220 lbs. This elevator is capable of being moved along the edge of the quay, and runs on rails of the ordinary gauge.

The rotating part of this elevator is carried on rollers running on a race CC supported by the upper frame of the travelling truck, and while the elevator is at work it is supported on jacks D resting on the edge of the quay wall.

The elevator can be altered to suit the varying water levels by means of a telescopic arrangement E, and the range of adjustment of the inner telescopic tubes, as well as of the buckets, is 7 metres. The edge of these tubes is lowest when their highest position is ½ metre above the rail level, as shown.

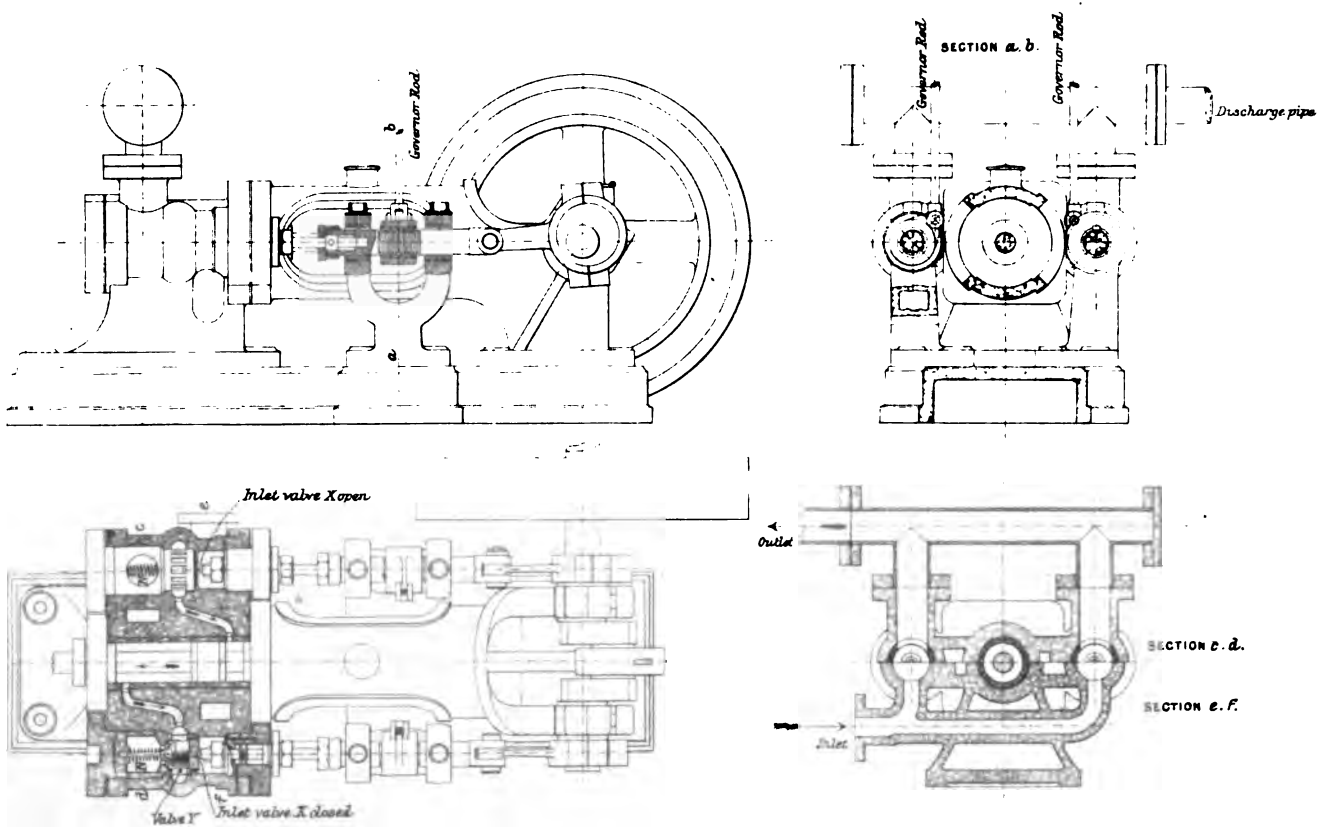
The adjustment of the telescopic tube can be varied either when the elevator is at work or when it is at rest, and the weight of the telescopic tube and buckets is balanced by counterweights FF at the back of the elevator. GG is the main driving belt. H is the windlass for lifting the telescope and the bucket belts. I is the band for transporting the grain, after it has been raised by the elevator, to the weighing machine. J is the high-pressure water main. K is the exhaust.

The elevator is raised or lowered by means of a 5 horse-power hydraulic engine, and can be placed at any desired part of the quay, and supplied with water at a pressure of 55 atmospheres from hydraulic mains, which are laid throughout the Harbour for this and other purposes.

The original driving engine was worked with a varying cut-off in the cylinder actuated by the governor. Air was admitted as well as water into the working cylinder, the former being expanded after the pressure-water had been shut off. This engine worked with very little noise, but consumed a great quantity of water, owing to the difficulty of keeping the valve tight on account of its large area. After a great deal of trouble had been taken in the matter, this valve motion was removed, and a patent arrangement of Mr. Miersch, the Locomotive Superintendent of the Harbour Works, was adopted, as shown by Plate 64. This motion is exceedingly simple, and has the minimum number of working parts.

It will be seen from Plate 64 that the water is led into the cylinder, and is exhausted from it, by means of two conical valves XX at the side of the cylinder. These valves are opened by eccentrics and are closed by water pressure. Their

HYDRAULIC ENGINE FOR MOVEABLE ELEVATOR, FRANKFORT.



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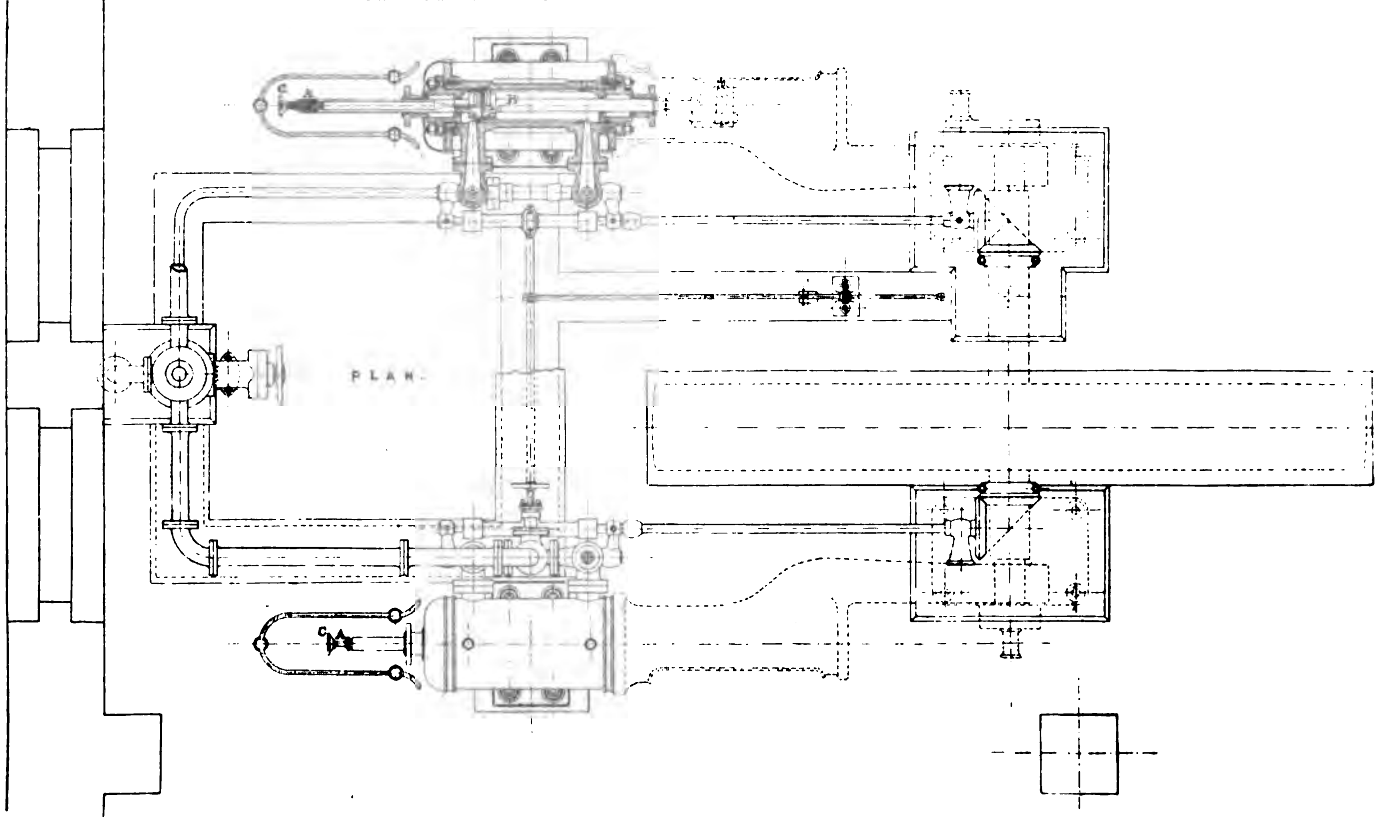

PLAN.
C
A

troke, and the time during which they remain open, are ontrolled by the governor.

Immediately behind each of the small admission valves here is a larger valve Y, which is moved by the water pressure at the instant the first valve is opened, and is closed against a seat, where it remains during the time the pressure water is entering the cylinder. Immediately the valve is closed it is pushed back again into its original position by means of a spring Z, and remains in that position until the valve X opens again.

By these means water is exhausted during the secondary closing of the valve controlling the water admission into the working cylinder, and during the return stroke of the piston water passes back out of the working cylinder into the exhaust pipe. By the application of this valve motion, which up to the present has given every satisfaction, the efficiency of the machine has been raised to 60 per cent.

The admission valves being nearly always tight, any want of truth can be easily remedied by removing the valve covers, and by grinding in the valves. The loss of pressure-water, owing to their not being tight, is very trifling, on account of their small size.

This engine makes 130 revolutions per minute, and the stroke of the piston is 120 millimetres, the diameter of the working cylinder being 80 millimetres.

In consequence of the efficient working of the Miersch gear in the portable elevator, the other engine in the granary, shown by Plate 65 in plan and side elevation, and in sectional elevation by Plate 66, is now being altered to work in the same way. This engine has two cylinders, and cranks at 90 degrees, and has a stroke of 500 millimetres, and a cylinder diameter of 144 millimetres, and at 35 revolutions per minute, is capable of giving off 60 horse-power.

In order to reduce the shocks in the pressure and exhaust pipes as much as possible, a very strong wrought-iron air-vessel is placed on the pressure pipe, close to the working

cylinders, and a large cast-iron air-vessel is placed on the exhaust pipe. Shut-off valves are placed on the exhaust as well as on the pressure side of each cylinder, so that should one cylinder break down, the engine can be worked at half-power by using the other cylinder alone.

Arrangements have been made by which the cylinders can be lubricated without opening them. In order to accomplish this, lubrication holes are drilled up the piston tail rods at A, and holes are provided radially in the pistons at B, the lubricant being forced into the holes by means of a hand-wheel and screw C, so that all surfaces are reached.

The valve gear is in principle similar to that in use in the working engine of the portable elevator; but the motion of the admission valves is not produced directly by means of eccentrics, but by means of two small supplementary valves which are actuated by the difference of pressure between the supply and the exhaust water, and by the difference in area in the motor piston valve connected to the admission valve. This motor piston valve has a rather larger diameter than the valve rod. When the valve is open the water pressure is constantly on its annular valve face, while the reverse side, with the full area, is alternately put under the influence of the pressure and exhaust water, owing to the successive opening of the two auxiliary valves, and in this manner the opening and closing of the supply valve is effected. The motion of the supplementary valves results from the rotation of cams, the position of which is determined by the governor.

PACKING.

For stuffing-boxes for rams, a gasket of hemp, plaited very tight, and well greased, is a very simple and durable packing. After it has become well consolidated the friction is but little, although at first it is considerable. A slight leak serves to lubricate the packing. Where the packing is exposed to heat,

hemp is a more suitable material to employ than leather. When the plaiting is done carelessly, the use of hemp is attended with the objection that portions are liable to be torn off when the gland is first packed and worked, and these pieces are liable to get into the valves. The packing, having to be compressed to meet the maximum pressure that the appliance may be worked at, the friction is a constant, although the machine may be working sometimes at a lower pressure, whereas with leather packing the friction varies directly with the pressure, and therefore the loss due to friction under varying pressures is less with leather packing than with hemp.

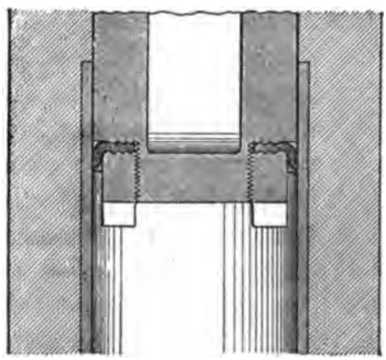


Fig. 52.

Benjamin Hick introduced the use of cupped leathers into presses, and the experience of his descendant, Mr. John Hick (referred to hereafter), affords valuable data as to the coefficients of friction with leather packing. A cupped leather forms a self-tightening packing, and is very generally used, although it soon wears out and fails when the cup is not properly supported at the bend (where the greatest friction is). This should be done by the insertion of a ring or bush of brass or gun-metal, which prevents the rapid wearing away of the bend of the leather. It has been found that when the cup has been made with a square, instead of with a rounded edge, the joint has not been so water-tight. A form of packing which has been found to answer well in the cylinders of hydraulic capstans is shown in Fig. 52.

Where the cup leather is placed in a shallow (instead of a deep) groove, there is not so much need of the support. The leathers are frequently made far too deep, and this leads to their being more liable to crack, and fail. Gutta-percha or india-rubber cups, and brass or lignum vitæ rings, have been used for packing, but on the whole the leather cup is the best. With a view to obviate the inconvenience and delay caused by the failure of a leather packing, "Watson's patent double leathers" are used in some presses. The neck of each cylinder has a provision for two leathers, one below the other, no pressure reaching the upper one until the lower one has worn out or burst. In that event the working of the press is not stopped as the second leather is brought into use by the attendant screwing down a valve while the press is working.

As the efficiency of hydraulic machines largely depends on proper packing, too much care cannot be taken in seeing that good leather only is used, and that the moulding of the cups is well done. The leather employed for making the cups ought to be of good and close quality, having had oil or tallow well rubbed into it after tanning. Before pressing the leather in moulds, to make the cup, it should be soaked in water till quite pliable, and after being forced into the mould it should be left for about twelve hours, then taken out, trimmed, allowed to dry, and afterwards replaced in the mould for an hour or two. It can then be removed and dressed to the required shape. The presence of gritty matter in the water injuriously affects leather packing, and involves frequent changing of the cups. Where dirty gritty water has to be used, the leathers wear away very rapidly when the cups are not kept constantly under pressure. If the pressure is taken off hydraulic machines by the accumulator resting on its bed, the water gets between the leather and the ram; and as soon as the accumulator rises off its bed, and the pressure comes on, a little gritty water passes between the leather and the ram, and causes the wear on the packing. An expedient which has been successfully adopted consists in putting a relief valve

on the pipe that delivers water to the accumulator from the pumps, and in leaving the suction valve always open. When the relief valve is lifted, at the top of the stroke of the accumulator ram, the pumps being always full of water, the accumulator cannot drop on to its bed. The pressure is in this way constantly kept on the leather, preventing leakage, and at the same time remedying the wear and tear of the packing. The employment of a gun-metal lining to the cylinder has been found to add to the life of the leather packing. The loss occasioned by friction in pumping into an accumulator having a well-packed stuffing-box (hemp packing being used) has been found to range from 3 to 8 per cent. at 700 lbs. pressure. The difference of pressure during the rise and fall of the accumulator represents from 1 to 2 per cent. of the power.

Experiments made by Mr. John Hick show that friction increases directly with pressure. With leather packing for rams of different diameters, if the pressure per unit of area be the same, friction varies directly as the diameters, or as the square roots of the gross loads. Neither the depth of the leather nor the length of the ram affects the total friction, since the effective portion of the cup is a curved surface where the contact takes place. With hydraulic machines in good order, the amount of friction may be taken to be 1 per cent. for rams of 4 inches diameter, and ½ per cent. for rams of 8 inches diameter, as will be seen by the table below.

From these experiments the following formula is deduced:—

$$F = \frac{P \times C}{D}$$

Where F = total friction of leather packing.
D = diameter of ram in inches.
P = pressure per square inch.
C = coefficient.

C = ·0471 with new, or badly lubricated, leathers.
C = ·0314 with leathers in good condition, and well lubricated.

The following Table of Mr. Hick shows the frictional

resistance in percentage of the total hydraulic pressure for rams from 2 inches up to 20 inches in diameter :—

D inches.	*F* per cent.	*D* inches.	*F* per cent.
2	2·00	12	0·33
3	1·33	13	0·30
4	1·00	14	0·28
5	0·80	15	0·26
6	0·66	16	0·25
7	0·57	17	0·23
8	0·50	18	0·22
9	0·44	19	0·21
10	0·40	20	0·20
11	0·38		

POWER CO-OPERATION.

The concentration at one or more points of the power necessary for the supply of water for domestic purposes (in the same way as gas and other requirements of daily life are produced from central stations) has suggested the desirability of developing at one establishment the power that is requisite to actuate machines at work in an area within reach of such centre. The principle has been termed by the author "Power Co-operation," and after advocating it for many years it is now gaining ground steadily. The facility with which power can now be transmitted to great distances, enables the co-operation of many power-consumers to be brought about. Bramah realised its feasibility in the following characteristic letter, which was written by him to Robert Mallet in 1802. Referring to the hydraulic press, Bramah wrote—"I think much might be done in Ireland in the press way if the excellence of the principle was but known; I have also now applied it with the most surprising effect to every sort of crane for raising and lowering goods in and out of warehouses. So complete is the device, that I will engage to erect a steam-engine in any part of Dublin and from it

convey motion and power to all the cranes on the quays and elsewhere, by which goods of any weight may be raised at one-third of the usual cost. This I do by the simple communication of a pipe, just the same as I should do to supply each premises with water. I have a crane on my own premises which astonishes every person to whom it has been shown—as they see the goods ascend and descend fifteen or twenty times in a minute to the height of 18 or 20 feet, and at the same time it is impossible for any person unacquainted with the principle to discover how or where the power comes from. I also show them pumps raising water with huge force, and a press squeezing wood, &c., to atoms, and not the smallest discovery can be made of the cause. I believe I shall have all the cranage of the London wet-dock warehouses to undertake, which will be the grandest job perhaps ever done."

Nearly thirty years ago the author promoted an Hydraulic Power Co-operative undertaking in Manchester, and the late Sir W. Fairbairn wrote in regard to it as follows :—

"Your proposal to erect steam-engines and lay down pipes for the purpose of working accumulators for supplying hydraulic power to different localities of the city of Manchester, seems to have several advantages over the system now in use in the different warehouses where steam is employed. In the first place, it would remove steam-engines and boilers from the premises, lessen the risk from fire and boiler explosions; and secondly, it would supply the necessary power to work cranes, hoists, hydraulic presses, &c., in those depôts on principles of increased security."

The experience of many years of the successful working of hydraulic machinery and appliances in government dockyards, railway termini, docks, wharves, &c., has proved it to be a most economical, convenient, and safe method of transmitting power over great distances, where the requirements are intermittent, as in the case of loading and discharging ships and railway trucks, lifting and lowering goods at wharves and

warehouses, working dock-gates, packing or pressing goods, actuating tools and machines in works. For these and for many other operations the number of labourers can greatly be reduced, as a system of power co-operation admits of the concentration of the whole engine and boiler power that are requisite to supply hydraulic pressure to an entire district at one or two points, by which the power is accumulated, and is distributed, at the minimum cost and trouble. Independent engines, boilers, and attendants can be dispensed with. The buildings and spaces occupied by these engines and boilers are rendered available for other purposes. The danger of fire due to the presence of boilers is avoided. The power is always available to meet the requirements of the consumer, and at a cost to him only in proportion to the power absolutely consumed.

HULL HYDRAULIC POWER COMPANY.

Hull was the first town in which high-pressure hydraulic mains were laid under the public streets for the supply of water-power on the co-operative system, and there the author carried out the first hydraulic power installation. The following description of these works was given in a paper read at the Institution of Civil Engineers in 1877 ("Robinson on the Transmission of Power to Distances"):—

"In the year 1872 an Act of Parliament was obtained for the purpose of establishing, at Kingston-upon-Hull, what was termed in the preamble 'a system for applying motive power by hydraulic pressure to waterside and land cranes, used for the purpose of raising and landing goods; and for working dock gates and other machinery.' The powers granted under this Act were to be exercised over an area of 60 acres, and they authorised the abstraction from the old harbour of the river Hull (a tributary of the river Humber) an amount of water not exceeding 1,000,000 gallons a day, for distribution

within the company's district, for which a payment was to be made to the Corporation of £12, 10s. per annum for each 250,000 gallons; the water to be used for no other purpose than as a motive power, except with the consent of the Corporation.

"A 6-inch pressure main has been laid from the nothern boundary of the defined area, near the Cottingham Drain, in a southerly direction along Wincolmlee, Trippett, Dock Office Row, under the Old Dock Basin (which forms the eastern or river Hull entrance to the Queen's Dock), and crossing this entrance it is laid along the whole length of High Street, terminating close to the western approach of the South Bridge across the river Hull. The length of pressure main, exclusive of the dock crossing, is altogether 1,485 yards, that on the north side of the dock entrance being 673 yards in length, and that on the south side 812 yards. Except at the dock crossing the main consists of cast-iron flanged pipes, of 6 inches internal diameter, 1 inch thick, with the usual spigot and faucet, and with gutta-percha ring joints tested to 2,800 lbs. per square inch before being laid, and afterwards to 800 lbs. per square inch.

"Stop-valves at intervals, having a waterway equal to that of the main, divide the main into sections. Air-cocks are fixed on all summits, by which the air is displaced in charging the main. T-pieces for 2-inch, 3-inch, and 4-inch branches are placed at convenient points, from which service-pipes can be carried to the various warehouses, works, &c.

"The main was laid across the dock-entrance, in a trench dredged to the inverts forming the dock bottom, the solid obstructions met with being removed and the bottom levelled by a diver. The pipes across the dock are of 6 inches internal diameter, made of welded wrought iron ¾-inch thick, bent to template to suit the curves of the sides and bottom of the dock, and were tested to 3,000 lbs. per square inch at the manufacturer's. They were put together at the side of the dock, and tested to ½ ton to the square inch before being

lowered into the trench. This was done from barges, and when the pipes were in position they were well concreted, to protect them from being injured by anchors or by weights falling overboard from ships. This part of the work has been tested in an unexpected way by the stranding of a large ship over the pipes, which, however, were in no way injured.

"The power to supply the water-pressure is concentrated at one pumping-station in Machell Street, where an engine-house has been built to receive four 60 HP engines. The ground being silty and bad, the foundations were carried down to the hard clay, a depth of 24 feet, the walls being built on arches resting on concrete piers. The engine-house is covered by a tank fitted with filtering boxes, through which the water pumped from the river Hull passes before it is delivered to the engines. Two pairs of high-pressure horizontal pumping-engines have been erected, each engine being of 60 HP, and capable of pumping 130 gallons per minute at 700 lbs. pressure per square inch, with steam at 100 lbs. pressure. The steam cylinders are $12\frac{1}{4}$ inches in diameter, and the length of stroke 24 inches; the force-pumps, which are double-acting, have a $4\frac{9}{16}$-inch piston, the piston-rod being $3\frac{1}{8}$ inches in diameter. Space is provided in the engine-house for two additional pairs of 60 HP engines, which can be erected at a future time when the demand for the water-pressure requires further engine power. Two Lancashire boilers, 22 feet 6 inches long, and 6 feet 6 inches in diameter, supply steam to the engines.

"An Appold centrifugal pump (in duplicate), fixed in the engine-house, draws the water from the river Hull, a distance of 125 yards, through a 10-inch pipe, and delivers it into the tank, the lift being 35 feet from low tide. The pump has an 8-inch suction, and is driven by a Brotherhood's 4-inch three-cylinder engine, also in duplicate. Each engine and pump supply 800 gallons of water per minute, with 100 lbs. steam pressure. A 6-inch return pipe is laid from the tank to the river, serving both as an overflow pipe and as a means of cleaning out the tank.

"One accumulator is erected at the pumping-station in Machell Street. It has a diameter of 18 inches, and a stroke of 20 feet. The case is loaded with 57½ tons of copper slag and sand, which produce a pressure of 610 lbs. per square inch in the main. Provision is made for an additional accumulator at the pumping station when required. Another accumulator will be placed at Grimsby Lane, towards the southern extremity of the line of main.

"Several observations were made to ascertain the useful effect of the engines and accumulator, and the mean was found to be 76 per cent., 5 per cent. being the loss in the pumps."

The plant has been extended since the commencement, by the addition of a third set of pumping engines, by doubling the capacity of the water tanks, and by the erection of a new accumulator in Grimsby Lane. The mains also have been extended, and are to be carried under the river Hull, by which power would be supplied on the east side of that river. The scale of charges issued 1st January, 1889 (subject to revision at the expiration of five years), was as follows:—There is a minimum charge of £2 per machine per quarter, the same rate being for 4,000 gallons of power-water, or less by meter. The quarterly charge diminishes as the quantity consumed increases, the table of rates varying from £2 per quarter for 4,000 gallons to £12, 10s. per quarter for 50,000 gallons, £20 for 100,000 gallons, £35 for 200,000 gallons, £50 for 300,000 gallons; above the 300,000 gallons special terms are arranged. Meter rent from 5s. per quarter.

LONDON HYDRAULIC POWER COMPANY.

The works at Hull have been followed by similar works in the metropolis, Messrs. Ellington & Woodall being the engineers. The London Hydraulic Power Company take the water from the river Thames, and the suspended matter is

partly removed by subsidence in storage tanks, divided into compartments, which form the roofs of the engine and boiler houses. The water is drawn off from these tanks by swivel pipes, with floats, to ensure the water being drawn off from the surface. It is then filtered by first passing it through animal charcoal in filters specially designed by Mr. Perrett, and constructed by the Pulsometer Engineering Company. The following description of them is given in a paper read before the Institution of Civil Engineers:—The filters consist of cast-iron cylinders, 5 feet in diameter, in groups. Each group contains two filters, one over the other. Each cylinder contains a movable perforated piston and a perforated diaphragm. Between the movable piston and the diaphragm is introduced a quantity of broken sponge. The sponge is compressed by means of a hydraulic ram, which gives a pressure of 10½ tons on the area of the piston, or about 4 lbs. per square inch on the sponge. While filtering, this condition is constantly maintained by hydraulic pressure from the mains. After the lapse of four to six hours, varying according to the state of the unfiltered water in the storage-tanks, the sponge becomes so clogged that the flow is seriously diminished in quantity, when the filter has to be cleansed.

Cleansing is accomplished by reversing the flow of water through the filters, and by opening communication to the wash-out pipes; at the same time, by means of the controlling valve in the hydraulic cylinder, the perforated pistons are caused to move up and down in the cylinders, alternately compressing and releasing the sponge, which, in the course of fifteen minutes or so, becomes thoroughly clean. The operation is comparable with that of rinsing a dirty sponge by hand. The filter is then set as at first, and filtering recommences. The filtering capacity of each group of two is 5,000 gallons per hour. There are five groups at present in use, the total capacity being 25,000 gallons per hour. Filtering is continued during the night.

In order to prevent waste due to leakage, a pressure gauge

is placed on the main at the pumping station, and by observing it during the night a leakage is indicated. By shutting the valves on the mains from a distant part of the system towards the station, and by applying a sounding rod, the leak can be located and its exact position determined.

The scale of charges issued by the London Hydraulic Power Company is intended chiefly for intermittently acting machinery. The charge is £1, 5s. as a minimum for each machine per quarter, or for 3,000 gallons and under, £6 per quarter for 20,000 gallons; £12, 10s. for 50,000 gallons, £20 for 100,000 gallons, £31, 5s. for 200,000 gallons, and £42, 10s. for 300,000 gallons. Above this quantity special terms are arranged, they being usually 2s. per 1,000 gallons beyond 300,000 gallons.

The extent to which the transmission of fluid through pipes has been carried out in America deserves special mention when speaking of power co-operation. In order to enable petroleum to be brought to the various commercial centres, independently of the ordinary channels of transport by road, rail, or river, a system of transmission through pipes was commenced in 1865. Oil was pumped from Pithole, in Pennsylvania, towards Oil Creek, a distance of 3,200 feet. Later in that year, another line of pipes was laid, through which oil was pumped a distance of 7 miles. The system grew, until in 1875 a 4-inch pipe was laid from the lower oil country to Pittsburg, Pennsylvania, a distance of about 60 miles. This main (as in previous cases) had to be guarded by armed men, to protect it from injury by those interested in other methods of transport. This system became ultimately recognised as the best method of conveying the oil from the place of production to the place where it was to be distributed; and the various lines of pipes became amalgamated (with a single exception) in one company, known as The National Transit Company. The length of pipes under the control of this company can be judged by the following figures:—The New York pipe is 300 miles; the Philadelphia pipe is

280 miles.; the Baltimore pipe is 70 miles; the Cleveland pipe is 100 miles; the Buffalo pipe is 70 miles; the Pittsburg pipe is 60 miles. The sizes of the pipes vary from 4 to 6 inches. The entire length of these pipes (including duplicate lines) is upwards of 1,300 miles; while the length of the collecting pipes of 2 inches diameter in the oil region is estimated to be from 8,000 to 10,000 miles.

BIRMINGHAM HYDRAULIC POWER.

The Corporation of Birmingham have recognised the advantage of a high-pressure water service, and an installation has been carried out by their water engineer, Mr. J. W. Gray, by which water, at a pressure of 730 lbs. to the inch, is pumped into a service of mains for distribution to consumers. The water in the ordinary mains of the town has a pressure of about 70 lbs. to the inch, and this has been largely employed to work lifts. By means of pumping engines and accumulators water from these mains is pumped into a high-pressure system of mains for utilisation for power purposes, thus effecting an economy in the amount of water consumed for power, at the same time those that require power are able to obtain it at less cost than with low-pressure water. The economy to consumers is twofold, inasmuch as the lifts that are worked by water at the higher pressure are less expensive than those for the lower pressure water, whilst only a tenth of the water is used.

The pumping arrangements at the station consist of three Otto gas engines, one of 12 horse-power and two of 20 horse-power, which drive three sets of triple hydraulic pumps. The 12 horse-power gas engine is started to work by hand, and pumps water into the accumulators. When the high-pressure water is available, it is turned on to work a 2 horse-power three-cylinder Brotherhood engine, upon the crank shaft of which is a drum 12 inches in diameter. By raising a lever the attendant can bring the revolving drum into position by which

it presses against the fly-wheel of the gas engine and puts it in motion, and when it begins to drive itself the hydraulic engine is shut off.

NIAGARA FALLS.

The water power of Niagara Falls has been utilised to a trifling extent by conveying the water from the river above the Falls by a canal (a distance of about three-quarters of a mile), and by discharging it at a point where it is employed for power purposes by a number of manufacturing works. These sprang up and absorbed all the power that was available, which led to arrangements being made, now approaching successful completion, for utilising a larger amount of the power of the Falls. A charter was granted in 1886 to the "Niagara River Hydraulic Power and Sewer Company of Niagara, N. Y.," whose scheme was to construct a tunnel about 1½ miles long to convey the water back to a district along the shores of the upper Niagara river, to be used there by millowners. In order to carry out this undertaking the "Cataract Construction Company" was formed for the purpose of constructing a tunnel, which commences at the river above the water level below the Falls, and passes under the City of Niagara to a large tract of land that has been acquired by the Company, near the river bank above the City. The shape of the tunnel is that of a horse shoe, 19 feet wide by 21 feet high inside the brickwork which lines it. The base of the tunnel, at its discharge point below the Falls, is 205 feet below the sill of the head gate at the entrance of the main canal from the river above the Falls. Of this fall 140 feet will be available, the rest being taken up by allowance for clearance from the wheel-pits, by the fall (of 36 feet per mile) of the lateral tunnels leading to the main discharge tunnel. A portion of the power will be sold to mills controlling their own wheels. At the central station the designs aim at

the utilisation at the outset of 20,000 horse-power, the tunnel itself being capable of conveying water representing 100,000 horse-power, which is calculated to be about 3½ per cent. of the whole flow. This is arranged to be employed for a variety of trading and other purposes, according to the following approximate scale of charge:—For 5,000 horse-power, $10 per horse-power per annum; for 4,000 horse-power, $11 per horse-power, and so down to 300 horse-power, for which $21 per horse-power per annum will be charged, the cost of a steam horse-power in Buffalo being about $35 per annum.

Several projects for utilising the water power have been submitted to the company. Two schemes (which received the highest premiums that were offered) proposed to utilise the power by turbines. Another proposed water-wheels. The methods of distribution that appear to commend themselves to the engineers, who are advising the company, are by electricity and by compressed air.

Professor Unwin, in his presidential address to the Mechanical Science Section of the British Association in 1892, stated that, in 1880, the total steam and water power that was employed in manufacturing operations in the United States was 3,400,000 horse-power, of which 64 per cent. was steam-power, and 34 per cent., or 1,225,000 horse-power, were from water. In Switzerland water-power has been utilised to a considerable extent, one firm alone, Messrs. Escher & Company of Zurich, employing 1,800 turbines, of an aggregate of 111,400 horse-power. The use of water-power has hitherto been limited to the immediate neighbourhood of the fall. Even with this limitation, works are in operation at Schaffhausen, Bellegrade, and Geneva, besides Zurich, whilst other projects are being matured to utilise the available water-power in Switzerland, which is estimated to be 582,000 horse-power, but the direction to be taken is in transmitting the power, from the point where it is produced, to distances, by electricity, compressed air, cables, or high-pressure water. There is no doubt that, in the near future, this will be accom-

plished, with the result of enabling many industries to be established and economically carried on, with great advantage to the commuuities that are fortunate enough to be within reach of these natural sources of power.

COST OF HYDRAULIC POWER.

The following data are useful in calculating power:—One pound pressure per square inch is equivalent to 2·3 feet head of water. The pressure of the atmosphere is 14·7 lbs. per square inch, which is equivalent to 34 feet head of water. As a gallon of water weighs 10 lbs., a flow of one cubic foot per second is equivalent to 375 gallons per minute. As a horse-power is 33,000 lbs. falling one foot per minute, and as a cubic foot of water weighs 62·355 lbs., one HP is 530 (nearly) cubic feet of water falling one foot per minute. This represents the gross HP, but the actual HP is less than this, depending on the efficiency of the prime mover. If 74 per cent. were to be taken as the coefficient of useful effect, 1 HP would be obtained from 716 cubic feet of water falling a foot per minute. As a pressure of 700 lbs. per square inch corresponds to a head of 1,613 feet, and as a gallon of water weighs 10 lbs., it follows that the available energy in a gallon of water at 700 lbs. is 16,130 foot-pounds. By employing this water-power at the rate of two gallons per minute, it would represent 32,260 foot-pounds, or nearly a horse-power.

The cost of hydraulic power was given in the before-mentioned paper by the author, that was read before the Institution of Civil Engineers in 1877, on the "Transmission of Power to Distances," as follows:—

"In the Albert Dock of the Hull Dock Company, a 60-HP engine supplies water for working an 80-feet swing-bridge, nineteen hydraulic engines working gates, sluices, and capstans, three 20-ton coal hoists, one 15-ton crane, one 3-ton crane, and thirty-four 1½ ton cranes. These machines are

worked at a pressure of 775 lbs. per square inch, through 5,350 feet of 5-inch pipe, 1,400 feet of 4-inch pipe, with 3-inch and 2-inch branches to the dock gates and warehouses. The cost of supplying water-power for the year 1875 was £1,367, 3s. 1d., which gives, after taking 80 per cent. as the useful effect of the water after delivery into the main :—

	d.	
Engine power, . . .	0·24	per 100 foot-tons.
15 per cent. for interest on capital and depreciation,	0·88	" "
	1·12	" "
Add for repairs, .	0·13	" "
	1·25	" "

"At Cotton's Wharf, London, there are ten 25-cwt. hydraulic cranes lifting 40 feet, four 2-ton single power cranes, one 4·2-ton double power crane and one 48-ton press worked at a pressure of 700 lbs. per square inch; the cost when only six cranes were in operation, which is the average number, was:—

	d.	
Engine power, . . .	0·63	per 100 foot-tons.
15 per cent. for interest and depreciation, . . .	1·26	" "
	1·89	" "

"The cost of labour at the cranes was 0·46d. per 100 foot-tons. If the whole of the sixteen appliances were working, the cost would be :—

	d.	
Engine power, . . .	0·23	per 100 foot-tons.
15 per cent. for interest and depreciation, . .	0·47	" "
	0·70	" "

"The labour at the cranes being the same as before, namely, 0·46d. per 100 foot-tons.

"At the St. Katherine Docks, engines of 140 HP nominal pump 5,000,000 cubic feet of water annually at 600 lbs. pressure through 1,200 yards of 7-inch main, supplying power

to work a swing-bridge and upwards of seventy-five cranes, hoists, and presses. The power exerted annually is nearly 193,000,000 foot-tons, or, taking 80 per cent. efficiency, more than 154,000,000 foot-tons.

	£
The cost of the engines, boilers, accumulators, pipes, and appliances, ...	= 35,000
Foundations of engines and boiler-house, .	= 12,000

"The cost of water delivered into the main, including coal, wages, repairs and supervision, is 10s. per 1,000 cubic feet. The cost of the water power is, therefore, as follows :—

	d.	
Engine power, ...	= 0·39	per 100 foot-tons.
15 per cent. for interest on capital and depreciation,	= 1·10	" "
	1·49	" "

"At the London Docks, engines of 185 nominal HP pump 7,000,000 cubic feet of water per annum, of which 4,250,000 cubic feet are pumped at 750 lbs. pressure through 1,450 yards of 5-inch pipe, 640 yards of 4-inch, and terminating with 550 yards of 3-inch. The remaining 2,750,000 cubic feet are pumped at 650 lbs. pressure through 750 yards of 6-inch pipe. These jointly work the swing-bridges, lock gates, and upwards of eighty cranes, hoists, presses, &c.

"The cost of water delivered into the main, including coals, wages, repairs, and supervision, is 10s. per 1,000 cubic feet. The cost of the power will, therefore, be as follows :—

	d.	
Engine power, ...	0·33	per 100 foot-tons.
15 per cent. for interest and depreciation, . .	0·88	" "
	1·21	" "

"At the Victoria Docks, engines of 280 nominal HP pump 8,000,000 cubic feet per annum at 780 lbs. pressure through 700 yards of 5-inch pipe, 2,000 yards of 4-inch, terminating with 200 yards of 3-inch pipe. The power exerted is 401,000,000

foot-tons, or 321,000,000 foot-tons at 80 per cent. efficiency; and this power is applied to working a swing-bridge, lock gates, capstans, and upwards of one hundred cranes and hoists.

"The cost of water delivered into the main, including coals, wages, repairs, and supervision, is 10s. per 1,000 cubic feet. The cost of the power will, therefore, be as follows:—

	d.	
Engine power, ...	0·30	per 100 foot-tons.
15 per cent. for interest and depreciation, . .	0·88	,, ,,
	1·18	,, ,,

"At the Great Western railway station at Paddington, a 70-HP engine supplies water at 700 lbs. per square inch to two waggon hoists, three hauling machines, twenty turntables, fifty-four 25-cwt. cranes, sixteen hoists, three capstan engines, three traversing tables, two drawbridges, one ticket-printing machine, and four dropping platforms. According to Mr. H. Kirtley, the average consumption of water is 25,600,000 gallons per annum, obtained from the Water Company at 4d. per 1,000 gallons, one-fourth being returned and three-fourths run to waste. The cost of supplying this appears to be 1·10d. per 100 foot-tons, taking 80 per cent. efficiency of water delivered, and allowing 15 per cent. for interest and depreciation, or adding 0·13d. per 100 foot-tons for repairs = 1·23d. per 100 foot-tons.

"At the Swansea Docks, the amount of water pumped in the year ending midsummer 1876 was 20,750,000 gallons, at 700 lbs. per square inch, and the working expenses were:—

	£	s.	d.
Coal and fuel, ...	1,056	19	9
Stores, ...	134	15	5
Wages, ...	699	14	1
	1,891	9	3

	£	s.	d.
Wages and repairs, ...	412	6	10
Materials, ...	244	7	6
	656	14	4

"The cost will, therefore, be, taking 80 per cent. for the useful effect of the water delivered into the main:—

	d.		
Engine power, ...	0·38	per 100	foot-tons.
15 per cent. (on £22,000) for interest and depreciation, .	0·66	"	"
	1·04	"	"

"The extra cost for wages, repairs, and materials would be 0·13d. per 100 foot-tons, making the total cost 1·17d. per 100 foot-tons.

"The following is a summary of the foregoing data, and represents the cost of water power at pressures varying from 600 to 780 lbs. per square inch, taking 80 per cent. as the efficiency of the water pressure after delivery into the main, and allowing 15 per cent. for interest and depreciation:—

Column No. 1 gives the cost of engine power per 100 foot-tons, and column No. 2 gives the total cost, allowing 15 per cent. for interest on capital and depreciation of plant.

	No. 1. d.	No. 2. d.		
Albert Docks, Hull, . .	·24	1·25	per 100	foot-tons.
Cotton's Wharf (maximum),	·63	1·89	"	"
Cotton's Wharf (minimum),	·23	0·70	"	"
Paddington, ...	...	1·23	"	"
Swansea, ...	·38	1·17	"	"
St. Katherine Docks, . .	·39	1·49	"	"
London Docks, . . .	·33	1·21	"	"
Victoria Docks, . . .	·30	1·18	"	"
Mean, .	·36	1·26		

The above figures may be subject to modification with the varying conditions of labour, &c.

The total cost of producing and distributing high-pressure water power at 700 lbs. pressure may be taken at from 6s. 6d. to 8s. per 1,000 cubic feet, according to the price of coal, and other varying circumstances.

The late Mr. B. Walker estimated that the cost of producing 1,000 cubic feet of water at a pressure of 700 lbs. per square inch was 6s. 7d. by the ordinary high-pressure non-condensing and non-expansive pumping-engine. With economical highly expansive surface-condensing engines the cost was reduced to about 4s. 3d. These figures were based on the coal costing 8s. per ton, and they included attendants' wages, interest at 5 per cent. on the capital expended upon engine-house, foundations, engines, boilers, accumulator, and pipes, together with the cost of the water for the boilers.

Reducing the above rates to the cost of 100 foot-tons, and allowing 80 per cent. as the useful effect of the water power, the price at 6s. 7d. per 1000 cubic feet is equivalent to 0·22d. per 100 foot-tons, and that at 4s. 3d. to 0·142d. per 100 foot-tons. Under some circumstances the cost is higher, and the price would be 8s. in the first case, and 6s. 6d. in the second. 8s. per 1,000 cubic feet, reduced in the same way as before for comparison, is equivalent to ·267d. per 100 foot-tons, and 6s. 6d. is equivalent to 0·22d.

Mr. Westmacott calculated that the cost of producing 1,000 cubic feet of water at 700 lbs. pressure at the Poplar Docks, London, was 6s. 7d. in the year 1878, was 5s. 7d. in 1879, and was 4s. 11½d. for the first half of 1880. The number of gallons pumped was at the rate of 55¼ million per annum in the first case, 69½ million in the second, and 77¾ million in the third. The work was done by six ordinary high-pressure engines, coal costing about 14s. 6d. per ton. Reducing these prices in a similar manner to those previously given, the cost per 100 foot-tons becomes respectively 0·22d., 0·186d., and 0·165d. To these figures must be added about 1s. 6d. per 1,000 gallons (equivalent to 0·313d. per 100 foot-tons) for wear and tear, and interest on capital, in 1878, and a propor-

tionately smaller amount for the years 1879 and 1880. As the amount of work done increased, the cost per 100 foot-tons diminished, and since at the time to which the statement referred the engines were not worked up to their full power, the cost would be probably still further reduced.

At Cardiff Docks with ordinary engines worked up to their full power, the cost (including fuel, stores, and working expenses) was 3s. per 1,000 cubic feet, equivalent to 0·1d. per 100 foot-tons.

METERS.

Many ingenious meters have been invented to enable the quantity of water flowing in a pipe to be automatically measured. Some of these (such as Parkinson's) are based on the principle that is employed for gas meters, the water being admitted to one side of a drum, which is divided into segmental compartments. This drum is caused to rotate by the entry of the water, which passes through it to the delivery. The quantity of water that each compartment holds being known, the volume that is passed by each revolution is measurable by a train of wheels connecting with a clock face.

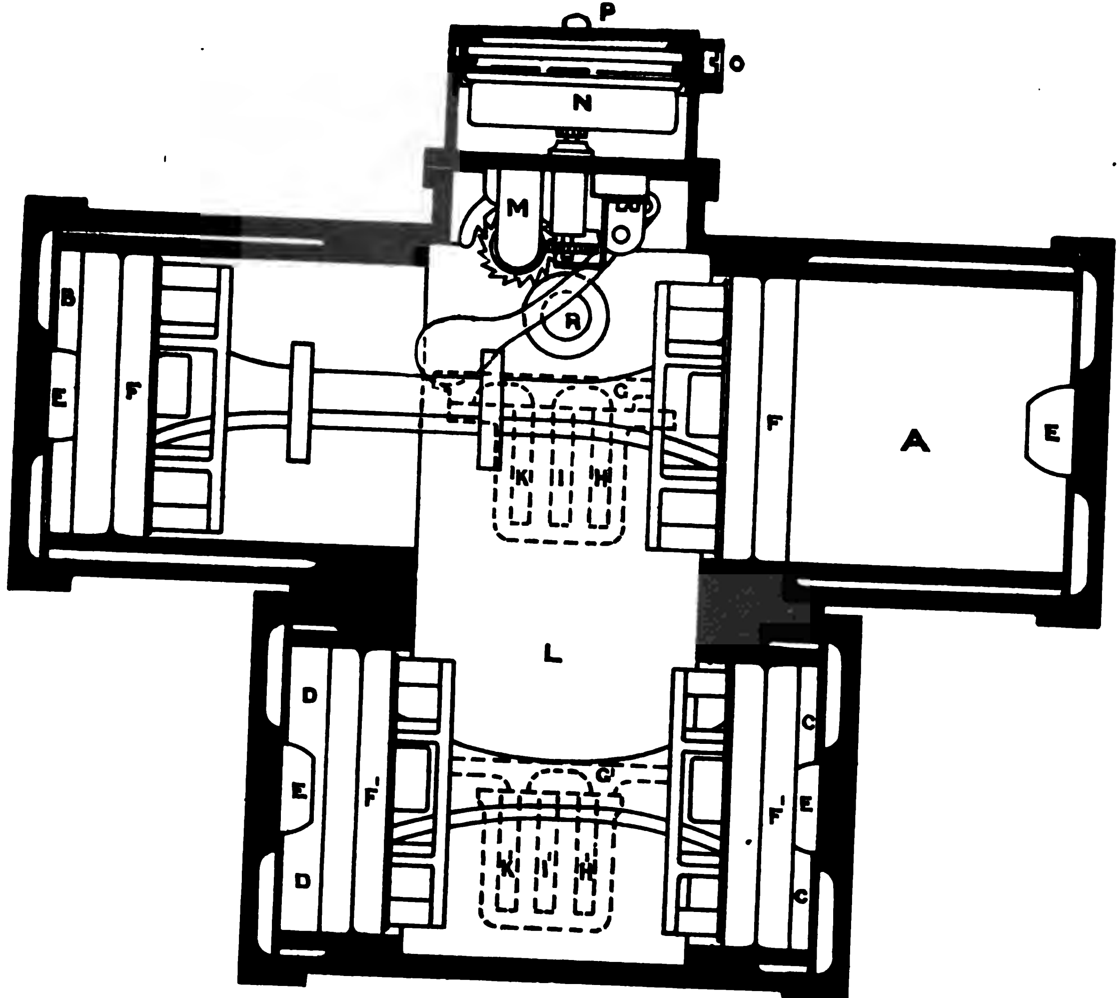
Another class consists of piston meters. In these the water, passing through a cylinder, forces a piston up and down, which actuates an index and records the volume that is passed. The admission and outlet are either through a four-way cock or through slide valves. Two types of this form of meter are Kennedy's and Frost's. In the Kennedy meter the stroke of the piston is reversed by a tumbler turning a four-way cock, through which both the supply and delivery water pass. In the Frost meter the reciprocating action is arranged by means of slide valves and ports reversed by an auxiliary piston. The piston in the Kennedy meter is packed with a rolling ring of india-rubber, and in the Frost meter it is packed by double cup leathers.

An application of the Reaction Turbine, or Barker's Vertical Mill, to the purpose of measuring water was made by the late Sir W. Siemens, and is called a Turbine Meter. In this appliance the water is admitted (by a fixed inlet) through a contracted entrance pipe to the top of the horizontal rotating wheel, and passes from it through spiral channels inside the drum, the reaction of the water producing a rotating action. This is regulated by vanes projecting from the revolving drum, which are adjusted so as to insure that the speed of rotation corresponds to the rate of flow, and is not disturbed by the velocity. Sir W. Siemens also devised the Fan Meter. In this the current of water acts on the circumference of the blades of a fan, which is caused to rotate by the water passing upwards through oblique openings on to the blades. The water afterwards flows away through a pipe in the top of the case above the fan. In the case are placed projecting plates to regulate the flow, by adjusting their sizes in proportion to the velocity.

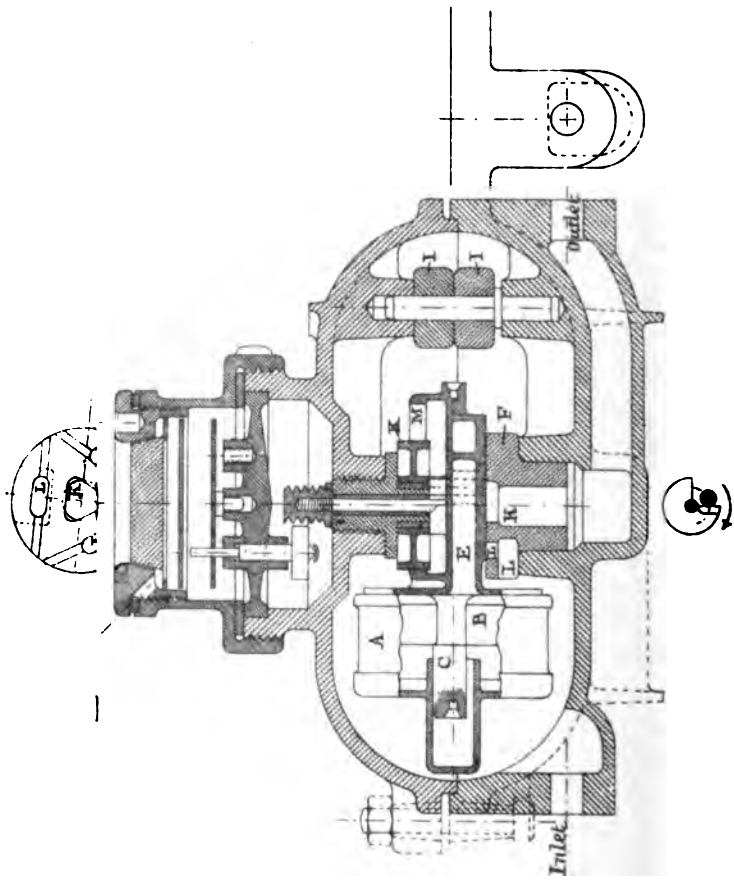
Another application of the fan system is that used in the Tylor meter. The water is directed upon the blades of the fan through oblique openings, and after it has acted upon the fan it escapes at a higher level. A feature in this meter is, that two or more blades are in the direct route of the water passing to and from the meter. It can be used as an automatic recording meter by placing it on a water-main, the leakage of water being recorded on the automatic diagram attached for this purpose. A portable meter may be attached to hydrants, separated by a valve, so that leakage may be detected at nights, when the district supplied by the main should be drawing no water.

Plate 67 shows the construction of the Tylor Piston meter. The water enters in the central space L by the opening R, and passes by the three-port valve G into the cylinder C by the port H. The piston F then reverses the valve G, and the water passes by the port H into the cylinder B, and so on. M and N show the registering mechanism. It will be seen

TYLER'S PISTON METER.



West, Newman Photo.



West, Newman Photo.

that there is no dead point in this meter, as each double piston reverses the valve for the other pair, and whatever the speed of the water, the pistons in each case must reach the end of their stroke. A modification of this meter is made in a vertical form, in which the registering apparatus is removed from contact with the water. This has been found necessary in many cases when corrosive water is used, or where deposits of calcareous matter take place on the mechanism.

The "Schönheyder" meter, like the "Kennedy" and the "Frost," is of the positive kind; but it differs from them in its construction. From Plate 68 it will be seen that the measuring chambers A are three cylinders of equal size, in which are fitted three pistons B with their tail-rods C. These pistons are cast in one with a central circular valve-plate, which has three ports D, and corresponding passages E, through the pistons, thereby communicating with the interior of the three cylinders A. The valve-plate with its pistons has a circular path, while the cylinders have side-way reciprocating movements. All the principal moving parts of the meter are carried by the stationary valve-seat F, the wings G of the cylinders being quite clear of the guide-lugs H, which are seen projecting from beneath the guide-rollers I. These wings prevent the cylinders from turning round on their axes, but permit a small downward movement, together with the pistons and the valve, due to the slight wear of the faces. The valve-seat F has one central exhaust port K, and three inlet ports L. The in and out movements of the pistons give the valve its circular motion, thereby causing its ports to be alternately in communication with the inlet and exhaust ports in the seat, and thus admitting water to, and exhausting it from, the cylinders in due course.

The length of the stroke of the pistons is determined by the difference in diameter of the circular roller path M cast on the top of the valve, and of that of a guide-roller N, mounted on a central pin depending from the cover. The

essential feature in this meter is the valve and its movement, for being circular (not revolving) the faces are soon polished true and so remain tight. On account of the circular movement of the valve, and the consequent gradually increasing and decreasing speed of movements of the cylinders, the meter works without concussion. There have been tests made from which it appears that the larger meters register to 1 per cent. and the smaller ones to within 2 or 3 per cent.

In order to equalise the pressure of water in the mains throughout a district having great variations of level, an appliance has been devised which is called "Key's Pressure Reducing Valve." This valve is of a globular form, and has a diaphragm cast in it, cutting off the high-pressure supply water from that in the low-pressure delivery pipe. This diaphragm is of irregular shape, its general direction being diagonally upwards from the bottom of the supply towards the top of the delivery pipe. It has a horizontal circular aperture, upon the circumference of which stands a fixed cylinder with holes in its sides, open at the bottom, and reaching to the cover of the valve. Inside this fixed cylinder another cylinder, with both ends open, is placed free to move up and down in it. To the top of this moving cylinder is fixed, by means of a crossbar, a piston-rod, which passes upwards through another cylinder of smaller diameter. To this rod is attached a piston which works water-tight in the smaller cylinder, the rod itself, which passes in through the top of the valve being loaded with weights. The action of the valve is as follows:—If the pipe is empty, the weights press the piston, &c., down upon a seating, by which, through the supply pipe, water is admitted. This encounters the diaphragm, and, passing upwards, surrounds the first-mentioned cylinder. It flows through the holes in the sides of this, goes through the moving cylinder into the lower part of the globular valve, and so out into the delivery pipe. When the latter is full, and the water begins to exert pressure, it presses upon the lower face of the piston, giving it a tendency to rise.

When the pressure reaches a point at which it can overcome the weights that hold down the piston, it forces up, and the rising piston carries with it the moving hollow cylinder which then (as it rises) closes the holes in the fixed cylinder, and thereby shuts off the water in the supply from that in the delivery pipe. By this arrangement the pressure can be reduced to any required extent by varying the weights upon the valves.

Another form of valve to effect the same purpose is Barton & West's Water-Pressure Reducer. In this valve, water from a supply pipe passes into a chamber in which is a vertical piston-rod with a piston head at top and bottom. The water acting on the under surface of the top piston, and on the upper surface of the bottom piston, balances the two, so that the flow of water has no tendency to raise or lower the rod, which passes upwards through the top of the valve chamber, and is acted upon by a weighted lever which tends to press it downwards. In so doing, it opens a circular aperture against which the lower piston closes when the valve is shut. When the valve is opened it allows water to pass through the aperture into a lower chamber, from which it flows into an outlet pipe. In the lower chamber the water presses against the lower surface of the bottom piston (or rather upon a portion of its surface, which is reduced in area by a cylindrical prolongation of its central portion) tending to force it up against the aperture. As long as this water-pressure in the lower chamber is less than that which acts upon the piston from the weighted lever, the piston will be held down. Water will then pass from the supply pipe through this aperture into the lower chamber, and thence into the outlet pipe. As soon, however, as the pressure in the lower chamber exceeds that transmitted by this lever, the piston will be forced upwards, and will close the aperture. By regulating the weight of the lever the pressure can be reduced to any required amount. The valve chambers are sealed at top and bottom by discs of india-rubber, through which the piston-rod passes, and which renders any

packing of the pistons unnecessary, as these india-rubber discs prevent leakage.

A "Water-Pressure Regulator" has been devised by Mr. Foulis. It is divided into an upper and lower chamber by means of a diaphragm, which passes from the upper side of the inlet in a diagonal direction to the under side of the outlet. In the centre is a circular aperture, the upper edge of which forms the valve seating. Vertically, under this aperture, and at the bottom of the chamber, is a short cylinder from which a small pipe communicates with the regulating apparatus, which is shown by the sectional diagram, Fig. 53. The valve A (formed to give a gradual opening) has the lower portion B acting as a piston working

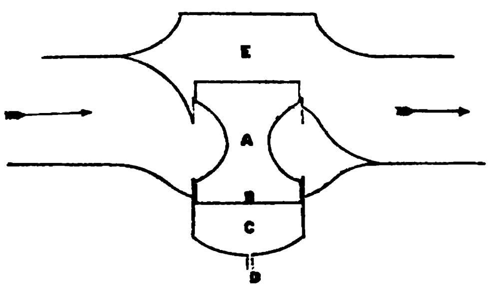


Fig. 53.

in the cylinder C. The pressure from the inlet, acting both underneath the valve and above the piston, is neutralised, and has no effect in moving the valve. A small pipe D communicates with a regulating apparatus, and gives the required pressure upon the lower side of the piston. Whatever pressure is applied below the piston, an equal pressure will be maintained above the valve, and in the outlet pipe. The pipe D is carried to a small hydraulic press having a ram about ½ inch in diameter, loaded with weights equivalent to the pressure that is desired in the chamber E. Another pipe puts this press in communication with the main inlet pipe, and it is also connected with the waste-pipe. The press and the various pipes are connected, so that as long as the pressure

in C does not exceed that desired in E, the ram remains stationary at its lowest point; but when this pressure is exceeded, the ram rises, thereby opening a communication between the pipe D and the waste-pipe, which immediately relieves the pressure in C, whereupon the valve A falls. This process is repeated as often as the pressure in C (and consequently in E) rises above that to which the hydraulic ram is set. Any rise in the outlet pressure, due to lessened consumption, will of itself close the valve A.

A modification of this valve is to make the piston B of smaller diameter than the valve, and to leave the chamber C open to the atmosphere. The separate regulating apparatus can then be dispensed with. In this case the inlet pressure on the valve is not completely balanced; but, acting on the greater area of the valve, tends to lift it, and will do so until the total outlet pressure on the top of the valve is equal to the total unbalanced inlet pressure.

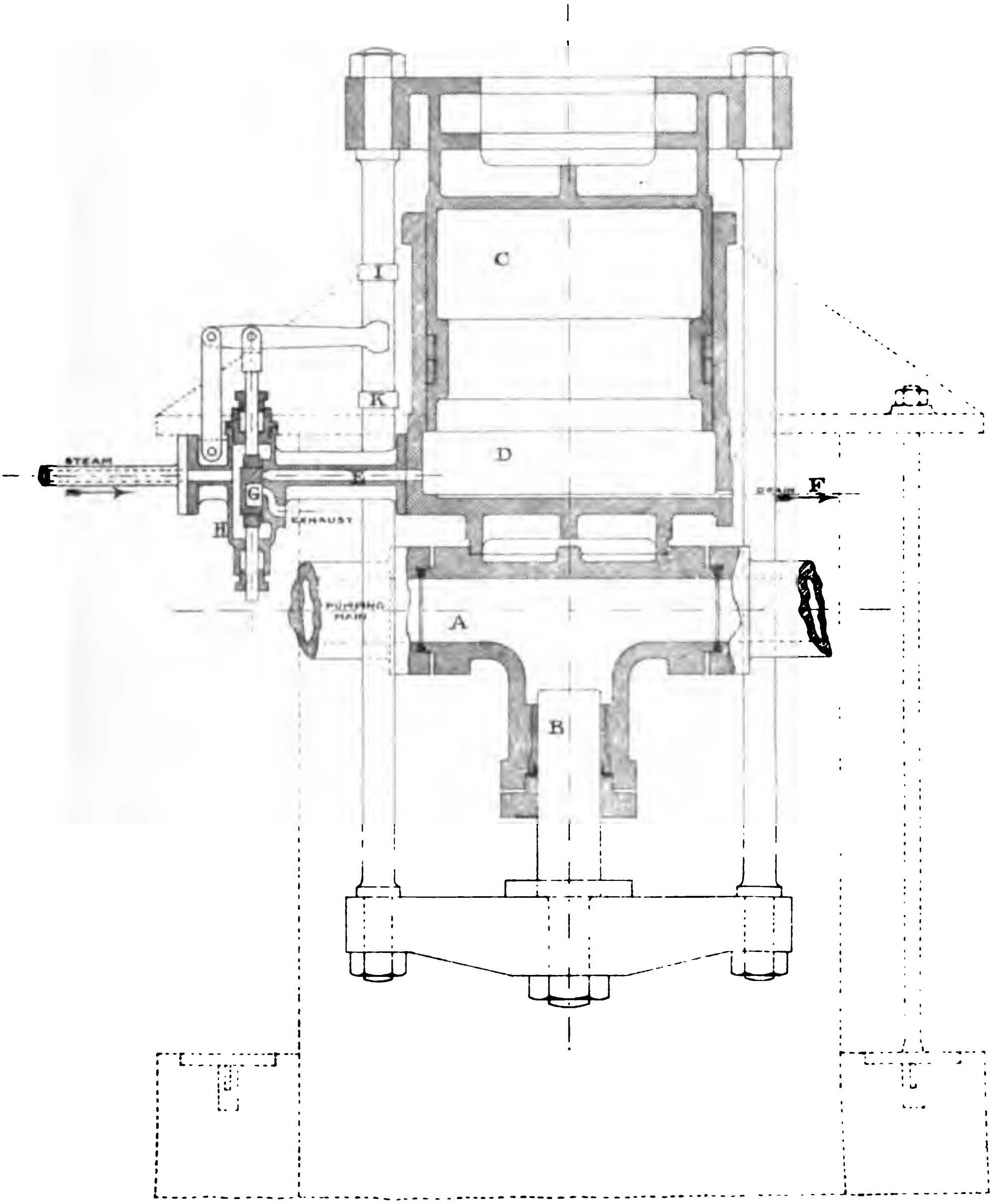
SCHÖNHEYDER'S PRESSURE REGULATOR.

In connection with pumping machinery generally, but more especially with that of the rotative class, it is necessary to provide an air-vessel, the function of which is to receive the excess of water delivered by the pump (above the mean flow) at certain periods of a revolution, and to supply to the main at other periods the deficiency (below the mean flow), so as to ensure a nearly uniform speed of water in the pumping main. Pumps of the "Duplex" and the "Three Throw" type have a fairly uniform rate of delivery, but when forcing into long mains it is usually considered necessary to provide even these with air-vessels. When, however, the pressures are very high, these cannot be used, as the air becomes absorbed by the water, and loaded plungers, springs, &c., have been employed as substitutes, but they are all deficient in power of regulating themselves according to the varying pressures in the main.

The automatic Pressure Regulator of Mr. W. Schönheyder is designed to meet this, and an illustration is given on Plate 69.

A is the pumping main through which the water flows from the pumping engine. B is a plunger, working freely through a leather or other packing. C is a plunger or piston connected to B, and working freely, but steam-tight, in the cylinder D. E is the steam admission passage and F the drain, which is furnished with a suitable regulating valve (not shown). G is a slide valve working in casing H, and in connection with these are the ports and passages. The valve G can be moved up or down by a rod and lever from the stops I and K, secured to one of the side-rods. Steam is supplied to casing H; the drain is kept slightly open for discharge of condensed water, and the working of the apparatus is as follows:—When the flow of water from the pump is below the mean, the plunger B will (by the action of the steam in cylinder D) be pressed inwards to supply the deficiency, and when the flow is in excess it will be forced outwards, slightly compressing the steam in D. Should the steam pressure in D be insufficient to balance the water pressure, the plunger B will be gradually forced out at each movement until the stop I comes in contact with the lever, thus forcing down the valve G and admitting more steam to the cylinder. Conversely, when the steam pressure in D is too high, B will be forced inwards, and the stop K will cause the valve G to be raised a little, thereby exhausting some of the surplus steam. It will be seen that the regulator is self-acting, and it has the further advantage over the ordinary air-vessel, that it does not require to be "charged"; for, from the moment that steam has been turned on to it, it is ready for work, and commences its regulating action directly the pump begins working. Air, or other convenient elastic fluid, may be used in place of steam. This regulator has been applied with success to several pumping installations. In one case two horizontal rotative pumping-engines delivered water through

SCHÖNHEYDER'S PRESSURE REGULATOR.



West, Newman. Pho

27 miles of 4-inch main, under a total head of nearly 1,000 lbs. per square inch.

DEACON'S DIFFERENTIATING WASTE-WATER METER.

This instrument measures the flow of water through a pipe and detects and localises leakage graphically. If a straight line represents no flow in a pipe, any leakage at a time when there ought to be no flow can be represented by a line parallel to this, and the flow at periods of demand at all times admits of being recorded graphically by a diagram having abscissæ for periods of time and ordinates for flow in gallons per hour.

The instrument designed by Mr. Deacon to accomplish this object is shown by Fig. 54. It consists of a truncated hollow cone A A, within which is a disc B, fitting the lower and smaller end of the cone, guided vertically, and loaded to counterbalance the pressure upon its under surface in excess of that upon its upper surface, due to the flow of water upwards between it and the sides of the cone. The disc is pressed upwards by the water rising below it, until this difference of pressure is exactly equal to the counterbalance. The counterbalance being constant, the difference of pressures (or loss of head) must be constant also. It follows from this that the annular orifice between the movable disc and the fixed cone is approximately proportional to the velocity in the pipe, and to the volume flowing past the disc. The orifice being proportional also to the height of the disc above its lowest or zero position, the volume of flow is approximately proportional to that height.

When no water passes, the fact is recorded upon the diagram C, by a pencil carried by a wire attached to the disc, and when a flow occurs the pencil rises, the height to which it rises being

approximately proportional at each instant, to the volume passing at that instant.

The diagram is caused to revolve by clockwork at D, and is so ruled horizontally that the heights are exactly proportional

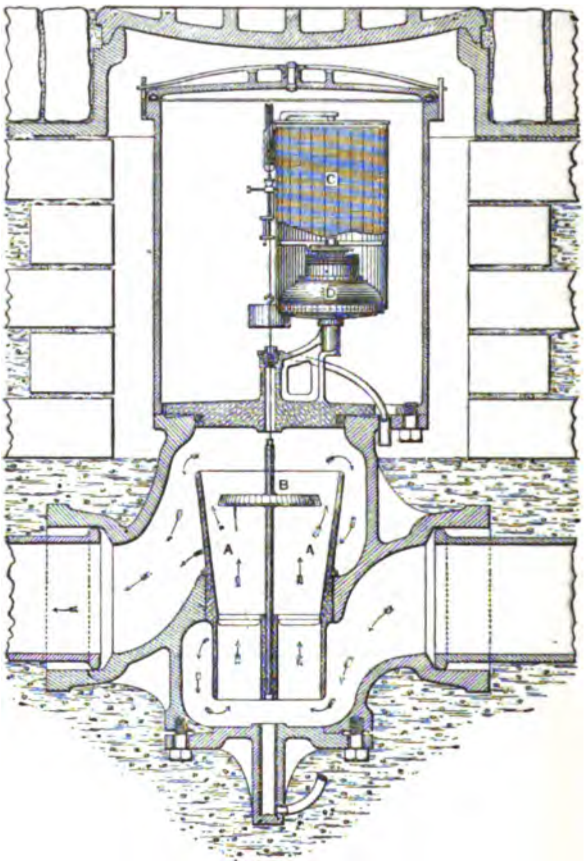


Fig. 54.

to the volumes. The actual volumes for each position of the disc in each class of meter have been very accurately ascertained by quantitative measurement.

Meters can be placed upon a system of water mains so that

each commands a certain district. The height of the uniform horizontal line in each meter shows the waste. An Inspector visits the district, where this leakage exists, at night. He listens at the stop-cocks in rotation with a rod, used like a stethoscope. By partially closing the stop-cock, so as to contract the area of the orifice, he can increase the sound. He closes those stop-cocks at which a sound is heard, and notes the position and time. The meter records simultaneously the time of each closing, and by the difference between the volume before and after each closing, it also records the leakage that has been prevented by that closing.

Another use of the meter, termed a disc gauge, is for the purpose of measuring the flow in large mains. One such is fixed near Oswestry on a 39-inch main of the Vyrnwy aqueduct for the supply of Liverpool. This instrument has proved useful, not only for the purpose of measuring the flow of water, but also as a means of checking the walksmen along the line of aqueduct, in connection with the opening and closing of the stop-valves.

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